The relationship of money and income: The breakdowns in the 70s and 80s

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The usefulness of the monetary aggregates as intermediate monetary policy targets depends crucially on the relationship between money growth and nominal income growth. The aggregates can function as reliable targets only if the effects of money growth on income are stable enough over time to be forecasted. Serious concern over the stability of this money/income relationship was raised several times in the 1970s and 1980s when velocity, the ratio of nominal GNP to M1, appeared to deviate from its trend rate of growth. The first such episode occurred from late 1974 through early 1976 when economic analysts were surprised by a sudden surge in velocity growth. In the latter 1970s, velocity resumed a growth rate more in line with historical experience. Concern over possible money/income instability subsided until 1982 and 1985 when there were two sharp drops in velocity. The explanations offered during each of these incidents tended to attribute the unusual velocity behavior to one-time shifts in money holdings precipitated by regulatory changes, financial innovation, or interest rate movements.

Such frequent occurrence of unexpected velocity shifts may indicate that the money/income relationship is subject to periodic instability. However, the velocity measure alone cannot provide conclusive evidence that serious breakdowns in the relationship have occurred. As a contemporaneous ratio, velocity cannot capture the full money/income relationship because it ignores the lagged influence of money growth on income growth. Velocity also cannot be used to test apparent changes in the money/income relationship for statistical significance.

This paper attempts a more formal documentation of the behavior of the money/income relationship during the three episodes brought to light by the velocity shifts. The seriousness of each incident is inferred from the performance of two reduced form models which explain nominal income growth as a function of current and lagged money growth and several other exogenous variables. One is the well-known equation developed by the staff at the St. Louis Federal Reserve Bank in the late 1960s.[1] The other is a similar model developed by Thomas Gittings of the Federal Reserve Bank of Chicago.[2]

These models can analyze the performance of the money/income relationship more rigorously than the velocity ratio can. First, they are more sophisticated measures of the relationship because they incorporate both the contemporaneous and lagged influence of money growth on nominal income. Second, they can be used to test statistically for shifts in the parameters of the relationship. Finally, since they are often used for forecasting, their predictive accuracy over time is an important indicator of the usefulness of the monetary aggregates as policy targets.

The stability of the money/income models cannot be statistically tested during the mid-1970s episode of unusual velocity behavior because the period is too short. However, the performance of the two models over that period does reinforce the velocity evidence that some sort of breakdown in the money/income relationship did occur. The in-sample errors of the two models are much greater from mid-1974 through early 1976 than in earlier years. Furthermore, the models substantially underpredict nominal income growth in 1975 and early 1976.

Statistical tests of both models do verify that the money/income relationship has undergone a major change in the 1980s. The two declines in velocity are accompanied by evidence of a significant shift in both money/income models. In addition, the models consistently overforecast nominal income growth from 1981 through 1985. Separate predictions of inflation and real income growth provided by the Gittings model indicate that the breakdown of the relationship occurs in both components of nominal income. How-

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ever, the shapes and timing of the inflation and real growth prediction errors are very different, suggesting that the two components might be breaking down for different reasons.

Past debate over the money/income relationship

The 1970s. Concern arose over possible instability in the money/income relationship in the mid-1970s. From mid-1974 through early 1976, the money demand equations in use at the time severely overpredicted money growth, and velocity grew much more rapidly than expected, particularly after the cyclical trough in early 1975. The most common explanations for the unexpected shortfall in money, called the "missing money," were that financial innovations and regulatory changes had reduced the cost of transferring assets between money and interest-bearing accounts, thus shifting money demand down (Enzler, Johnson, and Paulus (1976), Garcia and Pak (1979), Goldfeld (1976), Judd and Scadding (1982), Paulus and Axilrod (1976), Veazey (1977)).

The innovations most frequently cited were the growing use by businesses of repurchase agreements and cash concentration accounts to improve the efficiency of cash management. The regulatory changes thought to reduce money demand included the authorization of NOW accounts in New England, share draft accounts at credit unions, savings accounts for businesses and state and local governments at commercial banks, and telephone transfer and third-party payments services for savings accounts. Since these changes were considered permanent, the proponents of this explanation for the low growth in M1 thought that the increase observed in velocity was a one-time permanent shift.

Others argued that the prediction errors resulted from misspecification of the money demand equations, as well as money demand shifts due to financial and regulatory changes. Furthermore, these authors contended that the failings of the money demand equations were not indicative of a major change in the influence exerted by money growth on income growth. Tests for structural shifts in a St. Louis type equation and in the M1/GNP equation of the MPS (MIT-University of Pennsylvania-Social Science Research Council) econometric model concluded that the money/income relationship had remained stable in the early and mid-1970s (Hamburger (1977), McElhattan (1976)). Hamburger acknowledged that the St. Louis equation did not predict the steepness of the 1974-76 decline and recovery, but he claimed that forecasting procedures of all types quite often miss cyclical turning points in this manner.

The 1980s. After 1975, velocity growth appeared to return to normal until 1982 when it dropped sharply, leading many to assert that the money/income relationship had gone off track again. As before, much of the discussion of velocity's behavior focused on the demand for money. The explanations offered at the time, as summarized by Tatom (1983a), were that velocity shifted because of changed responsiveness of money demand to interest rates or inflation, growth of interest-bearing checkable accounts, increased foreign demand for U.S. money, and increased monetary volatility.

Judd (1983) argued that the money demand equation was stable over the period and that money holdings had increased due to the sharp decline in nominal interest rates in 1982. Judd and McElhattan (1983) then claimed that economic conditions in 1982 did cause a shift in the money/income relation, as measured by velocity, even though the money demand function remained stable. They argued that real interest rates stayed fairly high in 1982 because the decline in nominal interest rates was accompanied by a similar decline in inflation. As a result, nominal income grew at a sluggish pace, which when combined with the rapid growth of money holdings, caused velocity to fall.

Some attributed the 1982 velocity decline to the same type of regulatory change that was used to explain the velocity increase in the mid-1970s. Hamburger (1983) argued that the money demand function shifted upward in 1982 because of the nationwide introduction of NOW accounts in January 1981. This increased the rate of return on M1 since the NOW accounts were included in the M1 aggregate at the end of 1981. Hamburger claimed that his money demand equation predicted fairly well in 1982 once it included the NOW account rate of return on money.

Finally, Tatom (1983a, 1983b) contended that the 1982 velocity decline was normal for an economy on the verge of a cyclical recovery.

According to his argument, the 1982 increase in money growth led to a lagged increase in income growth in 1983, causing velocity to fall temporarily in 1982. This theory was tested using a velocity equation which included lagged money growth, interest rates, high employment government expenditure, inflation expectations, and slack productive capacity as explanatory variables. Structural tests of this equation yielded no significant evidence of a shift in velocity behavior in 1982. This was interpreted as implying that the money/income relationship had not changed significantly.

Velocity appeared to recover its trend rate of growth in the fourth quarter of 1983, but it began another dramatic decline in the fourth quarter of 1984, falling roughly six percent by the fourth quarter of 1985. The rapid growth in M1 reflected in the velocity decline was not matched by the growth in M2 or M3, the broader aggregates, over this period. Several analysts suggested that the velocity decline was due to a shift of funds to more liquid assets as long-term rates fell relative to short-term rates (Trehan and Walsh (1985), Wenninger and Radecki (1985, 1986)).

Wenninger and Radecki (1985) suggested that measurement problems also contributed to the 1985 drop in velocity. They claimed that GNP seriously understated the volume of transactions for which money was held in 1985 because net imports and sales out of inventory were unusually high that year. They showed that the in-sample errors of a reduced form money/income model were lower in both 1982 and 1985 when the GNP measure included such transactions.

As mentioned earlier, several researchers found that the erratic behavior of velocity in the mid-1970s was not accompanied by evidence of a significant change in the money/income models. So far the discussion of the 1980s velocity declines has not determined whether there has been a significant shift in the money/income relationship. The following sections seek to answer this question by testing the St. Louis and Gittings money/income models for stability in the 1980s. The models are also tested for a shift in the mid-1970s to confirm the findings of the earlier tests.

The St. Louis and Gittings money income models

The St. Louis and Gittings reduced form models express nominal income growth as a function of money growth in current and past quarters, and they both use polynomial distributed lags to estimate their coefficients. The two money income models differ in terms of the number of lagged values of money growth, polynomial degree, additional independent variables, and restrictions.

The St. Louis equation explains nominal income growth as a function of current and lagged growth in M1 and in high employment government expenditures. In this paper we follow a version of the St. Louis equation chosen by Batten and Thornton (1984) from among the specifications offered by six different model selection techniques. The version which dominates the others in a likelihood ratio test has 10 lags of money growth and nine lags of growth in high employment expenditures[3]

$$\dot{y}_t = \sum_{i=0}^{10} \alpha_i \dot{m}_{t-i} + \sum_{i=0}^{9} \beta_i \dot{g}_{t-i}$$

$\dot{y}$ = annualized rate of growth of nominal GNP

$\dot{m}$ = annualized rate of growth of M1

$\dot{g}$ = annualized rate of growth of high employment government expenditures

The polynomial restrictions found to be significant had six degrees for the money growth coefficients and seven or eight degrees for the government expenditure coefficients. In our estimations, we employ the seventh degree polynomial. We also use the cyclically adjusted budget expenditure series which replaced the high employment government expenditure series in 1983.

The Gittings model differs from the St. Louis equation primarily in that its lag structure is selected on economic rather than statistical grounds. The model assumes that money has a neutral impact on nominal income; that is, in the long run an increase in money is fully incorporated into the price level and has no lasting effect on real income. The model includes the number of lagged values of M1 growth necessary to satisfy this neutrality condition. (See box for an explanation of the neutrality restrictions.) We will follow the performance of a recent version of the Gittings model which uses 20 lags of money growth and a third degree polynomial distributed lag. This model also includes three lagged values of nominal income growth and the real price of energy in the two preceding quarters:

$$\dot{y}_t = \sum_{i=0}^{20} \alpha_i \dot{m}_{t-i} + \sum_{i=1}^{3} \beta_i \dot{y}_{t-i} + \sum_{i=1}^{2} \gamma_i \dot{e}_{t-i}$$

$\dot{e}$ = annualized rate of growth of real energy prices

The lagged endogenous variables partially incorporate the effects of non-monetary shocks. The energy price variables are included to improve the model's performance during the periods of rising oil prices in the 1970s.

Structural change in the money/income relationship

The St. Louis and Gittings models can be used to test the money/income relationship for instability during the episodes of unusual velocity behavior. Evidence from the two models generally confirms Hamburger's (1977) finding of no significant change in the relationship in the first half of the 1970s, although questions still remain concerning the models' performance from mid-1974 through early 1976. Both models indicate that the money/income relationship shifts significantly after 1981.

The 1970s. Hamburger's study of the relationship in the 1970s applies an F test to a version of the St. Louis equation to see if the coefficients change significantly after 1968.[4] He finds no significant shift in the coefficients between the period from 1953 through 1968 and the period from 1969 through the second quarter of 1976. However, he notes that this result does not necessarily imply that the relationship is stable. The tendency of the St. Louis equation to overestimate GNP growth before the second quarter of 1974 and to underestimate it afterwards suggests that there may be two opposing shifts in the relationship, one before 1974 and one after. When these quarters are combined in the second subsample of his F test, they might have offsetting effects on the model's parameters and thus lead to the finding of no significant change in the coefficients. To correct for this possible problem, Hamburger performs another F test using a second subsample which ends in the second quarter of 1974. Again, there is no significant evidence of a shift in the relationship.

Hamburger's test cannot be replicated exactly with the Gittings model and the Batten and Thornton version of the St. Louis equation because data limitations and the number of lags in the two models require that the samples begin after 1953. For the St. Louis equation, our F tests compare the model's coefficients estimated from the fourth quarter of 1961 through 1968 with those from Hamburger's second two subsamples, 1969 through the second quarters of 1974 and 1976. The two tests yield F values of 1.28 and 1.59, neither of which is significant at the five percent level. (See Table 1.) These results confirm Hamburger's finding that the St. Louis equation does not experience a shift in the first half of the 1970s.

The first subsample tested by the Gittings model begins in the second quarter of 1964, but otherwise the Gittings test samples match those used by Hamburger. When the second subsample ends in 1976, the coefficients of the two subsamples do not differ significantly from those of the full sample. But when it ends in 1974, the test is significant at the one percent level with an F statistic of 4.78. Thus, the results from the Gittings model could support Hamburger's hypothesis that offsetting shifts in the money/income relationship before and after 1974 prevent observation of any shift in the 1969 through 1976 period.

However, Hamburger's results are not conclusive evidence that the money/income relationship remains stable in the mid-1970s despite the sharp increase in velocity. His tests show only that the relationship is stable over the entire first half of the 1970s. They do not indicate whether the relationship is stable in the narrower period from mid-1974 through early 1976 when fears that the relationship had gone off track were actually raised.

Unfortunately, this period is too short to allow an F test of the stability of the money/income models. Some intuitive evidence about the performance of the relationship over that period can be obtained from the in-sample errors. When the St. Louis equation is estimated from 1961 through the second quarter of 1976, its mean squared error is 44

Table 1
Tests for structural shifts in the money/income relationship

	Sample periods	F value
Tests for shift in the early 1970s		
St. Louis equation	61 Q4-68 Q4, 69 Q1-74 Q2	1.28 - insignificant at 5% level
	61 Q4-68 Q4, 69 Q1-76 Q2	1.59 - insignificant at 5% level
Gittings model	64 Q2-68 Q4, 69 Q1-74 Q2	4.78 - significant at 1% level
	64 Q2-68 Q4, 69 Q1-76 Q2	.58 - insignificant at 5% level
Tests for shift in the 1980s		
St. Louis equation	61 Q4-80 Q4, 81 Q1-85 Q3	6.61 - significant at 1% level
Gittings model	64 Q2-80 Q4, 81 Q1-85 Q4	3.97 - significant at 1% level

percent higher from the third quarter of 1974 through the second quarter of 1976 than in the preceding quarters. The mean squared error of the Gittings model is 71 percent higher in the 1974-76 period than in the 1964-74 period. Although instability in the money/income relationship from mid-1974 through 1976 cannot be rigorously established, the erratic behavior of the money/income models over that period suggests that the relationship did experience some type of breakdown.

The 1980s. In the 1980s, the period of unusual velocity behavior is long enough for the stability of the money/income relationship to be statistically tested. Both the St. Louis and the Gittings models show very strong evidence that a shift in the relationship begins in 1981 and extends at least through 1985. A clear breaking point in the relationship is suggested by the in-sample errors when the two models are estimated through 1985. After assuming positive and negative values with fairly equal frequency throughout most of the sample, the errors become predominantly negative beginning in the second quarter of 1981. So, we test for a structural shift which starts in 1981.

For the St. Louis equation, our test looks for a shift in the parameters between the periods from the fourth quarter of 1961 through 1980 and from 1981 through the third quarter of 1985. This yields an F statistic of 6.61 which is significant at the one percent level. (See Table 1.) Thus, the coefficients of the St. Louis equation from 1981 through 1985 differ significantly from those in the years prior to 1981.

The structural test of the Gittings model compares the parameters estimated from the second quarter of 1964 through 1980 with those estimated from 1981 through the fourth quarter of 1985. Again, the test indicates a strong shift in the money/income relationship with an F statistic of 3.97 which is significant at the one percent level. Unlike the experience of the mid-1970s when a velocity increase is accompanied by inconclusive statistical evidence of a shift in the money/income relationship, the two velocity declines of the 1980s are indicative of a highly significant structural change.

The predictive performance of the money/income models

The erratic performance of the money/income relationship in the mid-1970s and the significant structural shift in the 1980s raise doubts over the usefulness of the reduced form models as tools to predict nominal income growth. This section attempts to replicate the short-term forecasting record that the St. Louis and Gittings models would have achieved in the 1970s and 1980s. The predictive ability of the two models is found to deteriorate in both the mid-1970s and the 1980s.

The short-term predictive performance of the two models is indicated by the errors of nominal growth forecasts one quarter in the future. The analysis assumes that forecasters use models estimated from the most current data. We examine the forecasts generated by estimations of the models from data that extend through the quarter just before the forecast. The St. Louis equation is estimated repeatedly with samples that begin in the fourth quarter of 1961 and end in every quarter from the fourth quarter of 1973 through the second quarter of 1985. These estimations produce one-quarter-ahead forecasts from 1974 through the third quarter of 1985. The Gittings model is estimated over samples beginning in the second quarter of 1964 and ending in every quarter from the fourth quarter of 1973 through the third quarter of 1985. This yields one-quarter-ahead forecasts for every quarter from 1974 through 1985.

The one-quarter-ahead forecast errors of the two models are plotted in Figures 1 and 2. The general drift of these errors is illustrated by the graphs of their cumulative values in Figures 3 and 4. Both models have a run of positive forecast errors in late 1975 and early 1976 which indicates that they consistently underpredict economic growth during the recovery from the 1974-75 recession.

Following that episode, the forecast errors of the Gittings model appear to move more or less randomly around zero throughout the rest of the decade. The model's cumulative forecast errors remain fairly level after the upward shift in 1975 and 1976. This suggests that the model does not consistently overpredict or underpredict economic growth over that period. The errors from the St. Louis equation also fluctuate around zero in the second half of the 1970s, but the positive errors tend to exceed the negative errors in absolute value. The cumulative errors slope upward during this period, reflecting the dominance of the positive errors.

In the 1980s, the predictive performance of both models deteriorates dramatically. Beginning in mid-1981, the forecast errors are predominantly negative with the exception of the fourth quarter of 1983 and the first quarter of 1984. The cumulative errors fall steadily, illustrating the persistence of the models' tendency to overpredict. The St. Louis equation overpredicts nominal growth by an average of three percentage points from 1981 through 1985, whereas it underforecasts nominal growth by an average of only 0.8 percentage points in the period before 1981. Similarly, the Gittings model overpredicts nominal growth by an average of 3.2 percentage points in the years after 1980, though its average error from 1974 to 1980 is an underprediction of only 0.5 percentage points.

The components of the 1980s shift

The one-quarter-ahead forecast errors offer further descriptive evidence about the nature of the 1980s shift in the money/income relationship. The models which produce the forecasts tend to reflect the money/income relationship prior to the 1980s because they are estimated from samples dominated by the 1960s and 1970s. Therefore, the forecast errors in the 1980s pick up the change in the relationship. This section examines the course taken by these errors over time, particularly as illustrated by the cumulative error graphs, in order to document the timing and configuration of the 1980s shift. Further information about the structure of the 1980s breakdown is provided by the forecast errors of separate inflation and real income growth equations estimated under the Gittings approach.

The cumulative nominal growth forecast errors of both models suggest that the 1980s change in the money/income relationship is composed of two separate shifts. The first occurs from 1981 until mid-1983 when the cumulative errors fall very rapidly from the rough plateau maintained in the latter 1970s. They level off again from mid-1983 through 1984, but in 1985 they begin another sharp decline which is very steep by the end of the year. The timing of these declines corresponds with the two abrupt drops in velocity in 1982 and 1985. This evidence of two shifts in the money/income relationship cannot be rigorously examined at present because not enough data is available for two structural tests over this period.

The breakdown in the money/income relationship can be evaluated further by examining the underlying patterns of inflation and real income growth. A fuller version of the Gittings model estimates separate equations for inflation and real growth which have the same number of lagged money growth, energy price, and endogenous variables as the Gittings nominal income equation. The two equations also impose the monetary neutrality condition that in the long run, money growth is completely incorporated into inflation and does not affect real income.

Figure 1
One-quarter-ahead nominal growth forecast errors—St. Louis equation

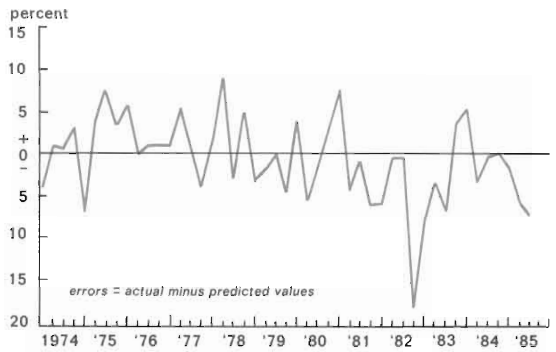


Figure 2
One-quarter-ahead nominal growth forecast errors—Gittings model

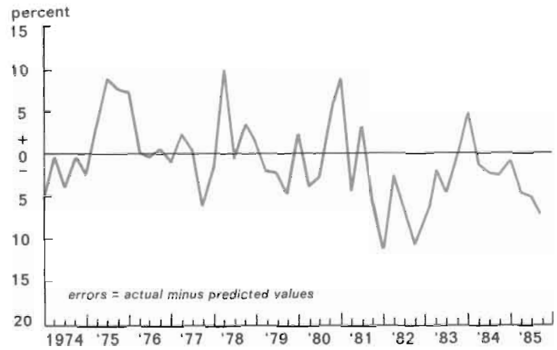


Figure 3
Cumulative one-quarter-ahead nominal growth forecast errors—St. Louis equation

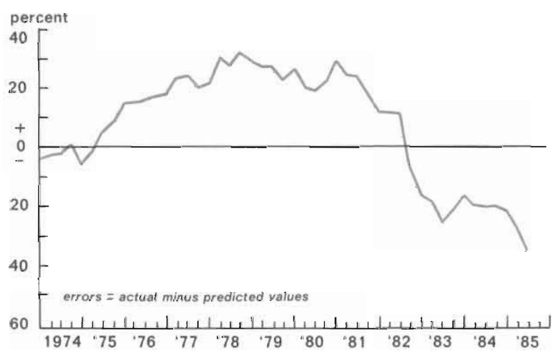
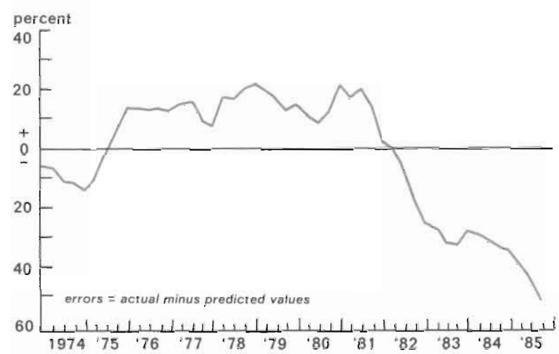


Figure 4
Cumulative one-quarter-ahead nominal growth forecast errors—Gittings model



The nominal growth forecast errors of both models appear to be much more closely tied to errors in forecasting real growth than errors in forecasting inflation. (See Figure 5.) The real growth forecast errors follow the nominal growth errors very closely throughout the sample, while the inflation forecast errors tend to fluctuate around zero until late 1982 when they become predominantly negative. Table 2 shows that the nominal growth forecast errors of both models are highly correlated with the real growth forecast errors over the entire sample and during the two periods when the money/income relationship goes off track. The correlation between the nominal growth forecast errors and the inflation forecast errors is much lower.

Despite the closer historical association between the nominal growth forecast errors and the real growth forecast errors, it is clear that the large nominal growth forecast errors in the 1980s result from poor prediction of both real growth and inflation. The cumulative inflation and real growth forecast errors illustrate the seriousness of the breakdown in the forecasts of both nominal income components. (See Figure 6.) However, the timing and shape of the two breakdowns are very different. The cumulative inflation errors slope steadily downward beginning in 1983, indicating that the Gittings inflation equation consistently

The current FRB Chicago—Gittings model

Since 1979 the Federal Reserve Bank of Chicago has been using a series of money income models developed by Thomas Gittings. These models have all been intended to capture the fundamentals of money growth's effect on the economy. The current model is a vector model. Changes in real income growth and inflation are modeled in two separate equations:

$$\dot{q} = \alpha_0^q + \sum_{i=1}^{L} \alpha_i^q \dot{q}_{t-i} + \sum_{j=0}^{M} \beta_j^q \dot{m}_{t-j} + \sum_{k=0}^{N} \gamma_k^q \dot{e}_{t-k}$$

$$\dot{p} = \alpha_0^p + \sum_{i=1}^{L} \alpha_i^p \dot{p}_{t-i} + \sum_{j=0}^{M} \beta_j^p \dot{m}_{t-j} + \sum_{k=0}^{N} \gamma_k^p \dot{e}_{t-k}$$

where $\dot{q}$ is the growth in real income, $\dot{p}$ is the inflation rate, $\dot{m}$ is the growth in M1, and $\dot{e}$ is the rate of change in real energy prices.

This model differs in a number of ways from money-income models used elsewhere. First, by separately estimating equations for real growth and inflation rather than estimating a single nominal income equation the tradeoff between real income and inflation can be directly forecasted. Benefits are also derived when the equations are not forecasting well (as all models of this type are prone to do periodically). The breakdown may occur in either the price or real income equation. By having an estimate of where the breakdown is occurring, it is easier to determine what may be causing the trouble and when it may end. Further, the FOMC may want to react to a fall in velocity differently if it is due to less than expected real growth rather than to less than expected inflation.

Second, lagged values of real growth and inflation are included. This gives the model a somewhat richer structure of time series behavior than models where no lagged endogenous variables are included, such as the various St. Louis equations. Our research indicates that the effects of money growth on the economy, especially inflation, are much more protracted than has previously been believed. The use of lagged endogenous variables allows us to model this without using an exorbitant number of lags of money growth.

Third, the rate of change in real energy prices is included as an additional tool to minimize the effect of supply shocks. Oil price shocks and their aftereffects on the entire spectrum of energy prices have been the dominant form of supply shock since 1973. By modeling this particular type of shock directly, the model provides better estimates of the money-income relationship. Without energy prices in the model the estimates of money's effect on both real income and inflation are both smaller and slower. This reduction in size and speed is typical of econometric estimation when a large source of error has been left unmodeled. Unfortunately, oil shocks are largely unpredictable and any direct gains in terms of forecasting are limited.

Fourth, because our research has led us to the belief that a large number of lags of money growth are necessary to correctly model the money-income relationship the danger of over fitting is large. To overcome this problem we use polynomial distributed lags to force the money coefficients to follow a smooth adjustment path. This effectively reduces the number of free parameters which can create artificially good regression results.

The last and most important difference is the application of the principles of neutrality and super neutrality directly to the specification and estimation procedures. Neutrality is a fairly old concept. It states that an increase in the rate of money growth will eventually cause an equal increase in the rate of inflation and that the rate of real growth will in the long run be unaffected. Without lagged endogenous variables this is equivalent to the statement that in the inflation equation the sum of the coefficients on money must equal one and that in the real growth equation they must sum to zero. For the case with lagged endogenous variables the constraints are slightly more complicated and can be written:

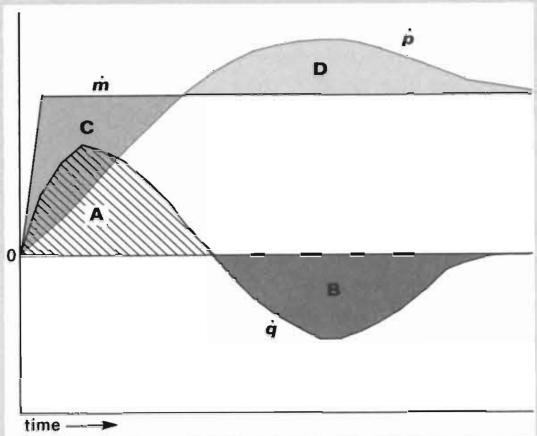
$$\sum_{j=0}^{M} \beta_j^q = 0, \qquad \sum_{i=1}^{L} \alpha_i^p + \sum_{j=0}^{M} \beta_j^p = 1$$

Super neutrality is a generalization of neutrality from rates of growth to levels. Simply put, it says that if the money supply is doubled it will lead to a doubling of the price level but will not affect the level of real income in the long run. Super neutrality comes from the rather straightforward belief that the Federal Reserve cannot create real wealth in the long haul simply by printing more and more money. Since the equations we use are in terms of rates of growth these concepts must be translated to restrictions on growth rates. The diagram shows the impact of a one percent increase in the rate of money growth on real income growth and inflation. In the real income case, the effect on cumulative real growth must be zero so area A must equal area B. In the inflation case it is only slightly more complicated. Inflation must on average equal the rate of money growth, implying that area C must equal area D. It follows after extensive manipulation that the restrictions on the parameters must be:

$$\sum_{j=0}^{M} j\beta_j^q = 0, \qquad \sum_{i=1}^{L} i\alpha_i^p + \sum_{j=0}^{M} j\beta_j^p = 0$$

By imposing the neutrality and super neutrality restrictions, we guarantee that the model will not imply that the Federal Reserve can create unlimited wealth by supplying greater and greater quantities of

Responses to changes in the rate of monetary growth



Coefficients of Gittings model equations

	Real GNP	GNP deflator	Nominal GNP
Intercept			
α_0	4.012	−0.243	4.402
Dependent variable			
α_1	−0.122	0.180	−0.145
α_2	0.014	0.218	−0.110
α_3	−0.102	0.074	−0.172
Money			
β_0	0.395	0.110	0.590
β_1	0.242	0.103	0.439
β_2	0.116	0.095	0.312
β_3	0.014	0.087	0.206
β_4	−0.064	0.077	0.119
β_5	−0.121	0.068	0.051
β_6	−0.159	0.058	−0.001
β_7	−0.180	0.047	−0.038
β_8	−0.186	0.037	−0.062
β_9	−0.179	0.027	−0.075
β_{10}	−0.162	0.017	−0.078
β_{11}	−0.135	0.008	−0.073
β_{12}	−0.102	−0.001	−0.062
β_{13}	−0.064	−0.009	−0.046
β_{14}	−0.023	−0.016	−0.028
β_{15}	0.018	−0.022	−0.008
β_{16}	0.058	−0.027	0.011
β_{17}	0.094	−0.031	0.028
β_{18}	0.125	−0.033	0.042
β_{19}	0.149	−0.033	0.049
β_{20}	0.163	−0.032	0.050
Energy			
γ_1	0.029	−0.010	0.010
γ_2	−0.090	0.075	0.016
R^2	0.386	0.688	0.305
F ratio	5.66	19.82	3.94
Neutrality Lagrange multiplier t-ratio	0.573	−0.065	0.642
Super neutrality Lagrange multiplier t-ratio	1.536	−1.563	−1.187

money, an implication of many money-income models that do not use such restrictions.

The restrictions can also be used to help determine how many lags should be included in the model. As can be seen from the diagram, if the lags are cut off too soon an unrestricted estimation of the equations would violate neutrality and super neutrality. Thus, we need to include enough lags so that the data is consistent with the restrictions. Use of this principle has led to longer lags than are typically used elsewhere. We believe many studies that have rejected super neutrality did so because they included too few lags. For instance, the current St. Louis equation uses 10 lags while our equations use 20 lags.

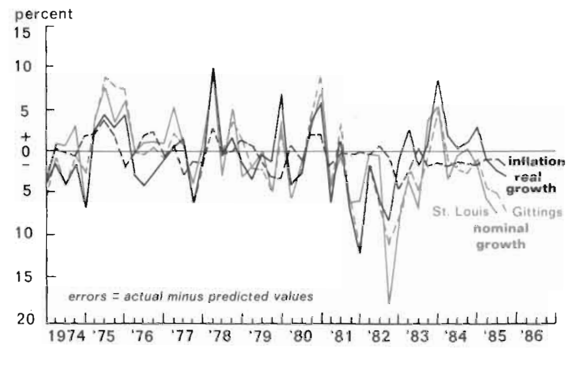
In order to to make easy comparisons with other reduced form models of nominal income, we also maintain a pure nominal income model, which is estimated with the same constraints as the inflation equation. A set of estimated equations for both the vector and single equation models are shown in the table. The sample was restricted to 64:Q2-81:Q4 in order to avoid the questions about the definition of money which have undermined the usefulness of the money-income relationship in the 80s, as the accompanying article documents. Current research is emphasizing techniques to forecast the breakdowns in the money income relationship so that we will have a better idea of when these relationships are useful for policy and when they are not.

—Thomas Gittings and Steven Strongin

overpredicts inflation from 1983 through 1985. The cumulative real growth errors fall rapidly in 1981 and 1982, remain fairly level throughout most of 1983, increase steadily from late 1983 through 1984, and then fall again in 1985.

The breakdown observed in the money/income relationship from 1981 through 1985 thus reflects the breakdowns of the real growth and inflation components at different points. The steep fall in the cumulative nominal growth errors is set off in 1981 by the

Figure 5
One-quarter-ahead forecast errors—Gittings and St. Louis models



overprediction of real growth. Overprediction of inflation starts to contribute to the nominal breakdown in 1983 just as the real growth equation begins to forecast fairly accurately for several quarters. The apparent stability of the nominal money/income relationship in 1984 actually results from offsetting errors in the inflation and real growth equations. Real growth is consistently underpredicted while inflation is consistently overpredicted during that year. But in 1985, negative inflation and real growth forecast errors reinforce each other, resulting in persistent overprediction of nominal growth.

The different patterns and timing of the cumulative inflation and real growth forecast errors suggest that the two nominal income components could be deviating from their past

Figure 6
Cumulative one-quarter-ahead forecast errors—Gittings model

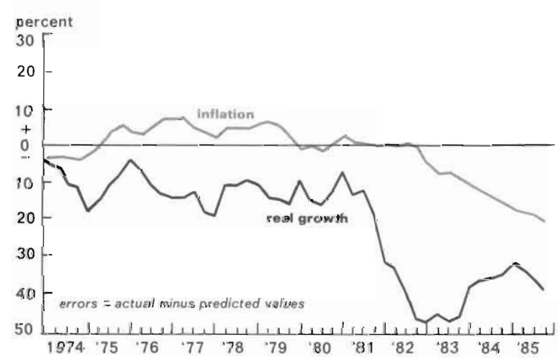


Table 2
Correlation between nominal growth forecast errors and real growth and inflation forecast errors

	Gittings Real growth errors	Gittings Inflation errors
1974-1985		
St. Louis nominal growth errors	.71	.33
Gittings nominal growth errors	.83	.45
1974 Q3-1976 Q2		
St. Louis nominal growth errors	.90	.03
Gittings nominal growth errors	.94	.30
1981-1985		
St. Louis nominal growth errors	.67	.23
Gittings nominal growth errors	.87	.22

behavior for different reasons. The constant decline of the cumulative inflation forecast errors suggests that the breakdown in the inflation equation might be caused by one factor or several persistent factors. The meandering course of the cumulative real growth forecast errors suggests that the breakdown of this process could be caused by several factors or the intermittent occurrence of a single factor.

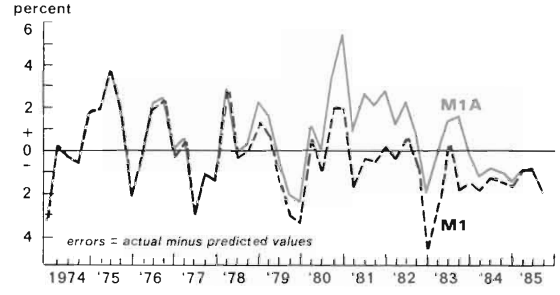
The inflation equation overpredicts by a steady average of 1.6 percentage points from 1983 through 1985, meaning that 1.6 percentage points of the M1 growth rate are not being incorporated into inflation. This suggests that the deterioration of the inflation equation's performance might result from mismeasurement of the monetary aggregate. Perhaps after 1982 M1 consistently overstates the transactions balances whose growth most monetarists believe determines the inflation rate. This could be because, as Kaufman and Strongin (1984) have argued, savings balances did not move in large numbers into the interest-paying components of M1 until interest rates fell in 1982.

Partial support for this view is provided when the Gittings inflation model is estimated with M1A, the aggregate which excludes all interest-bearing accounts and thus should not contain any savings balances. The M1A version does overpredict inflation after 1983 but not as seriously as the M1 version. (See Figure 7.) Thus, removal of all potential savings balances improves the forecasts but does not completely solve the mystery of the breakdown in the inflation equation after 1982.

This change in money definition improves the inflation predictions from 1983 through 1985 at the expense of poorer predictions in the early 1980s. From 1980 through 1982, the M1A model consistently underpredicts inflation while the M1 model performs very well. This is consistent with the Kaufman and Strongin argument that the interest-bearing accounts excluded from M1A primarily contained transactions balances before 1982.

The real income equation is clearly subject to episodic breakdowns in both directions. It is very difficult to speculate about the causes of such alternating bad and good performance without further research on the real income equation. However, it generally appears that the model is unable to incorporate the influence

Figure 7
One-quarter-ahead forecast errors—Gittings inflation equation using M1 and M1A



of real shocks which fundamentally alter the productivity of the economy.

The clear divergence between the shape and timing of the inflation and real growth forecast errors suggests that future research on the money/income relationship should study these two nominal income components separately. The neutrality-of-money proposition lends further support to this recommendation for it contends that money growth influences real income and inflation with different timing and long-term effect. Nominal income growth is determined merely as the product of the inflation and real growth processes. Separate study of money growth's influence on inflation and real growth in the 1980s would focus more directly on the root causes of the breakdown in the money/income relationship documented in this paper.

Conclusion

The behavior of velocity in the mid-1970s and the 1980s raised concern over the stability of the relationship between M1 growth and nominal income growth. This article has examined the behavior of two money/income models during each incident of unusual velocity shifts. The instability of the relationship in the mid-1970s cannot be statistically verified using these models because of insufficient data. However, both models predict very poorly during this period, which does indicate that the money/income relationship did not perform well in the mid-1970s. In the 1980s, there is overwhelming evidence of instability in the money/income relationship. From 1981 through 1985, the two money/income models experience a significant parameter shift, and they consistently overpredict nominal income growth.

The 1980s breakdown appears to be caused by unrelated changes in the inflation and real growth components of the money/income relationship. The fact that inflation is overpredicted at a fairly constant rate since 1982 suggests that the money/inflation relationship may be plagued by some persistent failing, perhaps the mismeasurement of the monetary aggregate. The real growth component of the money/income relationship, on the other hand, alternates between bad and good performance. This raises the possibility that the breakdown in the money/real growth relationship could be caused by a complex set of factors, some of which might be recurrent in nature. We are currently continuing our research in the hope of identifying the full range of factors which affect the performance of the inflation and real growth components of the money/income relationship and in particular to determine whether there are factors which cause periodic breakdowns. A better understanding of the economic conditions under which the money/income relationship does and does not perform well is required if the monetary aggregates are to be reliable policy targets.

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[1] See Leonall C. Andersen and Jerry L. Jordan, "Monetary and Fiscal Actions: A Test of Their Relative Importance in Economic Stabilization," Federal Reserve Bank of St. Louis *Review* (November 1968), pp. 11-24. The version of the St. Louis model followed in this paper is published in Dallas S. Batten and Daniel L. Thornton, "Polynomial Distributed Lags and the Estimation of the St. Louis Equation," Federal Reserve Bank of St. Louis *Review*, vol. 65, (April 1983), pp.13-25, and in Dallas S. Batten and Daniel L. Thornton, "How Robust Are the Policy Conclusions of the St. Louis Equation?: Some Further Evidence," Federal Reserve Bank of St. Louis *Review*, vol. 66, (June/July 1984), pp. 26-32.

[2] The accompanying box describes the Gittings model.

[3] Some versions of the St. Louis equation have included relative energy prices and a variable representing strike activity.

[4] Hamburger's version of the St. Louis equation is somewhat different from the Batten and Thornton version. It regresses nominal income growth on current and three lagged values of growth in M1 or alternatively, M2. The fiscal policy variables are measures of the "initial stimulus" of federal expenditures and receipts which correct for tax increases induced by inflation. These variables are scaled by nominal income four quarters earlier. The equation includes the current and two lagged values of the expenditures variable and the current and seven lagged values of the tax receipts variable. The model also includes the number of industrial man-hours lost due to strikes.

The F test used determines if a model's coefficients are significantly different when estimated over two separate samples than when the two samples are pooled as one sample. The regression is run over the two subsamples and the full sample. The regression's coefficients are found to shift significantly between the two subsamples if the sum of squared errors over the two subsamples is significantly less than the sum of squared errors over the full sample. The formula for the F statistic is:

$$F = \frac{(ESS_0 - ESS_1)/(k+1)}{ESS_1/(n_1 + n_2 - 2k)}$$

where ESS_0 = sum of squared errors over full sample

ESS_1 = sum of squared errors over the two subsamples

k = the number of parameters

n_1 = the number of data points in the first subsample

n_2 = the number of data points in the second subsample.

For further explanation of this test see G. S. Maddala, *Econometrics*, (McGraw-Hill, Inc., 1977), pp. 197-201.

References

Batten Dallas S. and Daniel L. Thornton. "How Robust Are the Policy Conclusions of the St. Louis Equation?: Some Further Evidence," *Review*, Federal Reserve Bank of St. Louis, vol. 66, (June/July 1984), pp. 26-32.

____________. "Polynomial Distributed Lags and the Estimation of the St. Louis Equation," *Review*, Federal Reserve Bank of St. Louis, vol. 65, (April 1983), pp. 13-25.

Enzler, Jared, Lewis Johnson and John Paulus. "Some Problems of Money Demand," *Brookings Papers on Economic Activity*, (1:1976), pp. 261-82.

Garcia, Gillian and Simon Pak, "Some Clues in the Case of the Missing Money," *American Economic Review*, vol. 69, (May 1979), pp. 330-334.

Goldfeld, Stephen M. "The Case of the Missing Money," *Brookings Papers on Economic Activity*, (3:1976), pp. 683-739.

Hamburger, Michael J. "Behavior of the Money Stock: Is There a Puzzle?" *Journal of Monetary Economics*, vol. 3 (1977), pp. 265-88.

____________. "Recent Velocity Behavior, the Demand for Money and Monetary Policy," in *The Proceedings of the Conference on Monetary Targeting and Velocity*, Federal Reserve Bank of San Francisco, (December 4-6, 1983), pp. 108-36.

Judd, John P. "The Recent Decline in Velocity: Instability in Money Demand or Inflation?," *Economic Review*, Federal Reserve Bank of San Francisco, (Spring 1983), pp. 12-19.

____________, and Rose McElhattan. "The Behavior of Money and the Economy in 1982-83," *Economic Review*, Federal Reserve Bank of San Francisco, (Summer 1983), pp. 46-51.

____________, and John L. Scadding. "The Search for a Stable Money Demand Function: A Survey of the Post-1973 Literature," *Journal of Economic Literature*, vol. 20 (September 1982), pp. 993-1023.

Kaufman, George G. and Steven Strongin. "The Decline in Income Velocity in 1982: Is There A Mystery?" Paper presented at the Midwest Economics Association Meetings, Chicago, (April 5-7, 1984).

McElhattan, Rose. "Has the Money-GNP Relationship Fallen Apart?" *Economic Review*, Federal Reserve Bank of San Francisco (Summer 1976), pp. 34-43.

Paulus, John and Stephen H. Axilrod. "Recent Regulatory Changes and Financial Innovations Affecting the Growth of the Monetary Aggregates," Washington, D.C.: Board of Governors of the Federal Reserve System, 1976.

Tatom, John A. "Alternative Explanations of the 1982-83 Decline in Velocity," in *The Proceedings of The Conference on Monetary Targeting and Velocity*, Federal Reserve Bank of San Francisco, (December 4-6, 1983), pp. 22-66.

____________. "Was the 1982 Velocity Decline Unusual?" *Review*, Federal Reserve Bank of St. Louis, vol. 65, (August/September 1983), pp. 5-15.

Trehan, Bharat and Carl Walsh. "Examining the Recent Surge in M1," *FRBSF Weekly Letter*, November 15, 1985.

Veazey, Edward E. "Monetary Policy—A Changing Relationship Between Money and Income," *Review*, Federal Reserve Bank of Dallas, vol. 65, (April 1977), pp. 1-10.

Wenninger, John and Lawrence J. Radecki. "The Monetary Aggregates in 1985," *Quarterly Review*, Federal Reserve Bank of New York, vol. 10, (Winter 1985-86), pp. 6-10.

____________. "Recent Instability in M1's Velocity," *Quarterly Review*, Federal Reserve Bank of New York, vol. 10, (Autumn 1985), pp. 16-22.