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MONEY, INCOME AND PRICES AFTER THE 1980s

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ABSTRACT

Three empirical findings presented in this paper show that evidence based on the most recent U.S. experience does not indicate the kind of close or reliable relationship between money and nonfinancial economic activity that, if present, might warrant basing the design and implementation of monetary policy on money in a formally systematic way: First, extending the familiar time-series analysis to include data from the 1980s sharply weakens the evidence from prior periods showing that such relationships existed between money and nominal income, or between money and either real income or prices considered separately. Focusing on data from 1970 onward destroys this evidence altogether.

Second, the finding by Stock and Watson that particular forms of time-series experiments still showed a significant role for money in affecting real output through 1985 not only becomes weaker on the inclusion of data from 1986 and 1987 but also, even for data through 1985 only, turns out to depend on the use in their analysis of a particular short-term interest rate, the Treasury bill rate. Using instead the commercial paper rate, which apparently is superior in capturing the information in financial prices that matters for real output, also greatly weakens their result. Simultaneously using the commercial paper rate and including data through 1987 destroys it altogether.

Third, extending the analysis through 1987 also destroys the time-series evidence from earlier periods showing that money and income are co-integrated. Even if monetary policy were to be conducted in terms of targets for money growth, the failure of money and income to be co-integrated means that there is no empirical ground for resisting the "base drift" that results from persistent random differences between actual money growth and the corresponding target.

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MONEY, INCOME AND PRICES AFTER THE 1980S

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Economists have long understood that the quantity of money, or its growth rate, can play a useful role in the monetary policy process only to the extent that fluctuations in money over time regularly and reliably correspond to fluctuations in income, or prices, or whatever other aspects of economic activity the central bank seeks to influence. The same is true, of course, for any other financial quantity -- non-money assets, for example, or measures of credit -- or, for that matter, interest rates and any other financial prices. Especially in the case of money, a rich literature developed over many years has investigated in some detail the requirements that the relationships connecting money to income and/or prices must satisfy in order to warrant focusing monetary policy on money in any of several specific ways.[1] An equally rich empirical literature has repeatedly sought to establish whether these requirements have actually been satisfied at specific times and in specific places.[2]

Different ways of conceptually basing the monetary policy process on money place different empirical requirements on the relationships between money and the economic variables that are of ultimate policy concern. These relationships in turn depend on such basic dimensions of economic behavior as the nature of the economy's aggregate supply process, the degree of price flexibility, the interest and wealth elasticities of aggregate demand, and, importantly, the public's money demand behavior and the banks' money supply behavior. For example, under familiar circumstances using money as an "intermediate target" -- that is, determining the money growth rate most likely ex ante to be consistent with the central bank's macroeconomic policy objectives, and then conducting monetary policy operations during some time interval as if achieving money growth along that path were itself the policy objective -- is the closer to being optimal as the demand for money is the closer to being both nonstochastic and interest inelastic. Looser relationships suffice for it to be optimal to use money as an "information variable" -- that is, adjusting policy operations during some interval in response to actual money growth that departs from the ex ante path, and perhaps also in response to analogous departures for other variables, but in any case not in a way designed necessarily to restore money growth to the ex ante path.[3]

What is essential to either of these ways of proceeding, however -- and to others besides -- is that there be at least some reliably exploitable connection between money and either income or prices, so that observed departures of money from some ex ante path bear a systematic implication for income or prices in the future. Otherwise money, as a variable that the central bank cannot set directly as a policy instrument, has no role in the policy process. From an information-variable perspective, there is no point to the central bank's reacting to fluctuations in money if those fluctuations bear no implication for subsequent movements in income or prices. From an intermediate-target perspective, there is even less point to making policy as if controlling money were stochastically equivalent to controlling income and prices if in fact there is no relation between them.

It is for just this reason that the events of the 1980s have proved so subversive to what had almost come to be standard ways of formulating and implementing monetary policy, not just in the United States but in many other countries as well. While there was never any lack of debate about the strength or weakness of the empirical relationships connecting money to income and prices, and therefore about the appropriate role of money in the monetary policy process, before the 1980s there was widespread agreement that fluctuations in money did contain at least potentially useful information about future income and price movements. In the 1980s, however, the empirical basis underlying that agreement has disappeared. Empirical investigation based on sample periods that include the 1980s simply does not lead to results corroborating what were commonly accepted as facts of economic behavior not so many years earlier. It is not surprising that in this environment some central banks, including the Federal Reserve System in the United States, have altered or abandoned the ways in which they had previously relied on money to make policy.

The object of this paper is to show how the passage of time -- in particular, the experience since 1980 -- has altered familiar empirical relationships previously taken to support a central role for money in the monetary policy process. Section I reports results for a variety of regression and autoregression tests, in each case seeking to establish whether fluctuations in money are useful for predicting subsequent fluctuations in income or prices. Here the consistent finding is that the positive results familiar from earlier time periods do not hold up when the sample is extended to include data from the 1980s. Section II digresses to focus on the role of the interest rate in the Stock-Watson tests. Here the main result is that, even within the earlier sample period, the finding of a significant role for money in explaining subsequent movements in income depends critically on the use in the analysis of a particular interest rate that is unlikely to reflect debt market fluctuations accurately. Section III reports results for tests of the co-integration of movements money and income. Here, as in Section I, the relationships that would have to hold in order to warrant using money as the central focus of monetary policy disappear when the analysis includes data from the 1980s. Section IV briefly concludes by drawing together the implications of these respective findings for monetary policy.

I. Regression Tests

Table 1 presents a set of $\bar{R}^2$ coefficients to summarize the performance, across different financial aggregates and across different time periods, of simple "St. Louis" eqations relating the quarterly growth rate of nominal income in the United States to lagged growth rates of a financial aggregate and government spending. Each equation is of the form

$$\Delta y = \alpha + \sum_{i=1}^{4} \beta_i \Delta m_{t-i} + \sum_{i=1}^{4} \gamma_i \Delta g_{t-1} + u_t \tag{1}$$

where y, m and g (all in natural logarithms) are, respectively, nominal income, the financial aggregate indicated, and high-employment federal expenditures; α, the β_i and the γ_i are coefficients to be estimated; and u is a disturbance term.[4]

For the sample spanning 1960:II-1979:III -- that is, from the earliest time for which the Federal Reserve provides data corresponding to its current definitions of the monetary aggregates, until the introduction of its new monetary policy procedures in October 1979 -- these equations all exhibit the modest success in accounting for nominal income growth that has become so familiar in the literature. The $\bar{R}^2$ values range from a low of .23 for the monetary base to a high of .32 for M1. Extending the sample to include data through yearend 1986 sharply lowers the $\bar{R}^2$ for each aggregate, however, leaving not one as high as .20. Going on to drop the observations from the 1960s, thereby focusing on the most recent seventeen years of experience, eliminates the explanatory power of these equations almost altogether. For the 1970:I-1986:IV sample, not one of these equations has an $\bar{R}^2$ even as high as .10.

Ever since the early work of Sims (1972), however, empirical consideration

TABLE 1

COEFFICIENT OF DETERMINATION FOR NOMINAL INCOME EQUATIONS

	1960:II-1979:III	1960:II-1986:IV	1970:I-1986:IV
Monetary Base	.23	.10	.02
M1	.32	.11	.02
M2	.27	.19	.06
M3	.27	.16	.09
Credit	.29	.10	-.02

of whether money (or any other aggregate) can usefully play a role in the monetary policy process has focused not just on whether past fluctuations of money help predict fluctuations of income (or prices, and so on) but on whether they help predict fluctuations of income that are not already predictable on the basis of past fluctuations of income itself and/or other readily observable variables. Especially in the context of the information-variable approach to monetary policy, the much debated issue of whether statistical tests along these lines constitute valid tests of "causality" is beside the point. As long as movements in money do contain information about future movements in income beyond what is already contained in movements in income itself, monetary policy can exploit that information by responding to observed money growth regardless of whether the information it contains reflects true causation, reverse causation based on anticipations, or mutual causation by some independent but unobserved influence.

Table 2 presents F-statistics for tests of the null hypothesis that all of the coefficients on the lagged growth of either M1, M2 or credit (that is, the β_i) are zero in equations of the form

$$\Delta y = \alpha + \sum_{i=1}^{4} \beta_i \Delta m_{t-1} + \sum_{i=1}^{4} \gamma_i \Delta g_{t-1} + \sum_{i=1}^{4} \delta_i \Delta y_{t-1} + u_t \qquad (2)$$

where all variables are defined as above. The table also shows F-statistics based on analogous equations excluding the government spending variable. Once again, the results are for three sample periods: 1960:II-1979:III, 1960:II-1987:II and 1970:I-1987:II.

The F-statistics in Table 2 show that, as of 1979, each of M1, M2 and credit contained information about future income movements that was

TABLE 2

F-STATISTICS FOR NOMINAL INCOME EQUATIONS

	1960:II-1979:III	1960:II-1987:II	1970:I-1987:II
Fiscal Variable Included			
M1	5.99***	2.83**	1.92
M2	4.20***	4.11***	1.67
Credit	4.79***	1.02	.16
Fiscal Variable Excluded			
M1	6.16***	2.63**	1.42
M2	4.32***	4.43***	1.86
Credit	3.97***	.91	.41

* Significant at .10 level
** Significant at .05 level
*** Significant at .01 level

statistically significant at the .01 level, regardless of whether the analysis includes the fiscal variable. Merely including data through 1987 reduces the significance of M1, and eliminates it altogether for credit. Dropping the data from the 1960s renders not one of the resulting F-statistics significant even at the .10 level.

Table 3 presents analogous F-statistics for equations in which the variable whose movements are to be explained is not nominal income but either real income or the price level. As is consistent with much of the existing literature, the pre-1980 evidence is mixed, depending on which aggregate the equation includes, whether the dependent variable is income or prices, and whether or not the equation includes the fiscal variable.[5] Nevertheless, through 1979 each of these aggregates contained statistically significant information about at least one of real income or prices, under at least one specification. Including data through 1987 eliminates most of these positive results. Dropping the data from the 1960s eliminates them altogether, except for one F-statistic (out of twelve -- about what would be expected in the context of no systematic relationship whatsoever) that remains significant at the .10 level.

Not surprisingly, as such findings first began to appear they prompted a search for alternative specifications that would continue to reveal a statistically significant role for money in explaining movements of income and/or prices. The most widely known such effort is perhaps that of Stock and Watson (forthcoming), who showed that money (M1) did have statistically significant effects on subsequent movements of real income (proxied by industrial production) in appropriately specified equations based on U.S. monthly data for February 1960 through December 1985. In their preferred specification -- including six lags on each of real income, prices (the producer price index), money, a short-term interest rate (the three-month Treasury bill

TABLE 3

F-STATISTICS FOR REAL INCOME AND PRICE EQUATIONS

	1960:II-1979:III	1960:II-1987:II	1970:I-1987:II
Fiscal Variable Included			
Effect on Real Income			
M1	2.17*	2.21**	1.91
M2	3.63**	4.47***	2.01
Credit	1.95	.60	.08
Effect on Prices			
M1	3.65***	.74	.88
M2	1.00	.30	.18
Credit	2.92**	1.64	1.50
Fiscal Variable Excluded			
Effect on Real Income			
M1	1.98	1.91	1.33
M2	3.58**	4.62***	2.39*
Credit	1.68	.63	.15
Effect on Prices			
M1	3.62**	.68	.47
M2	1.08	.40	.28
Credit	3.00**	1.76	1.58

* Significant at .10 level
** Significant at .05 level
*** Significant at .01 level

rate) and a linear time trend -- the F-statistic for the null hypothesis that all six coefficients on lagged money are zero was 3.04, easily significant at the .01 level.

Table 4 presents F-statistics summarizing the results of replicating Stock and Watson's tests using data through September 1979, then through December 1985 as in their work, and then through September 1987. The results are for Stock and Watson's preferred specification (including a linear time trend) and also for two variants that they used: one with no time trend at all, and one with both linear and quadratic trends.

In the results based on the pre-1980 data, neither the F-statistic for Stock and Watson's preferred specification nor that for the variant including the quadratic trend is significant at even the .10 level. (In this context it is no surprise that the literature through that time did not emphasize the inclusion of trends.) As in Stock and Watson's results, the F-statistics for all three specifications are highly significant in the results based on data through 1985. Data revisions not incorporated by Stock and Watson change the three F-statistics only slightly. Including the data from 1986 and 1987 sharply lowers all three, however, leaving none -- not even that for the preferred specification -- significant at the .10 level. Moreover, results (not shown) for a variety of Stock-Watson-type specifications based on quarterly data for 1960:II-1987:II reconfirm these results even more broadly. In no case is the F-statistic for money significant, even at the .10 level, in analogously specified equations for nominal income, or, for that matter, in analogous equations for prices.[6]

TABLE 4

F-STATISTICS FOR EFFECT OF MONEY IN STOCK-WATSON TESTS

Trends Included	1960:2-1979:9	1960:2-1985:12	1960:2-1987:9
None	2.69 (.016)	2.45 (.025)	1.03 (.404)
Linear	1.56 (.159)	2.96 (.008)	1.61 (.143)
Linear, Quadratic	1.50 (.179)	2.47 (.024)	1.39 (.220)

Note: Numbers in parentheses are marginal significance levels.

II. Interest Rates and the Effect of Money on Output

Following the work of Sims (1980), it has become customary in tests for effects of money on real output to control for the effect of interest rates. Money growth, after all, is not the only potential source of information about the state of financial markets, nor the only potential measure of whatever effects financial phenomena may be exerting on real economic activity. Comparative examination of tests using different monetary aggregates or credit aggregates, as in Section I., have long been standard. In recent years, however, most studies have broadened the class of financial variables that may potentially be of use in this context to include not just financial quantity variables, like money and credit, but also financial price variables including interest rates.

A typical finding in such work is that the results of tests for the effect of money on output is highly sensitive to whether or not the analysis also includes an interest rate. One especially interesting feature of Stock and Watson's findings, therefore, was the limited nature of this sensitivity that they reported. True, deleting the interest rate from their preferred specification raised the F-statistic for the test of the effect of money on output from 3.04 to 3.50. The more important point is that even the smaller value, for the system including the interest rate, was significant at the .01 level.

Although the inclusion of an interest rate in empirical work of this kind has become standard, there has been little discussion in the literature of just which interest rate is appropriate. Moreover, what little discussion there is has focused on such matters as the difference between long-term rates (with their inherent anticipatory properties) and short-term rates, rather than on apparently more mundane questions like which short-term rate makes the most sense to use.[7] Sims (1980) and Friedman (1983) both used the commercial paper rate, while Litterman and Weiss (1985), Eichenbaum and Singleton (1986) and Stock and Watson (forthcoming) all used the Treasury bill rate.[8] None of these authors, however, offered substantive arguments in support of the selection made.

Just as different monetary aggregates correspond to different conceptual ways of measuring financial market quantity information, different short-term interest rates correspond to different conceptual ways of measuring financial market price information. In the case of the commerical paper rate -- that is, the interest rate on short-term unsecured borrowing by corporations in nonfinancial lines of business -- and the Treasury bill rate -- that is, the analogous unsecured borrowing rate for the U.S. Government -- there are substantive grounds on which to question which one provides the better gauge of financial prices that matter for the determination of real economic activity.

At the most obvious level, the commercial paper rate more directly reflects the cost of finance corresponding to potentially interest-sensitive expenditure flows than does the Treasury bill rate. To the extent that interest rates matter for nonfinancial economic activity primarily because they affect the behavior of private-sector borrowers, therefore, any influence that causes these two rates to covary imperfectly will make the commercial paper rate superior to the Treasury bill rate as a measure of this effect. For example, when changes in the perceived creditworthiness of the average business alter the spread between the rate on potentially defaultable commercial paper and that on presumably default-free Treasury bills, as often happens over the course of a typical business cycle, it is the commercial paper rate that conveys more information about the borrowing costs that may affect spending flows. By contrast, to the extent that interest rates matter for nonfinancial activity primarily by affecting the behavior of those who save and invest, rather than of those who borrow, the Treasury bill rate is plausibly more relevant.

The interest rates on commercial paper and Treasury bills covary imperfectly for reasons other than time-varying perceptions of creditworthiness, however. Because many of the other sources of this imperfect covariation reflect technical oddities of the Treasury bill market, rather than anything directly bearing on the role of interest rates in affecting nonfinancial economic activity, in the end the commercial paper rate is probably the better measure regardless of whether borrowers' or lenders' behavior is the more important in this regard. Short-term fluctuations in the Treasury's cash flow alternately swell the supply of bills or increase the demand (by forcing banks to present eligible collateral against enlarged tax and loan account balances). These fluctuations occur in part on a seasonal basis, but also in part irregularly. Fluctuations in the volume of advance debt refundings by state and local governments, as sometimes occur in anticipation of changes in tax legislation, also affect the demand for Treasury bills (because of legal restrictions on these borrowers' options for temporarily re-investing advance refunding proceeds). So do fluctuations in the Federal Reserve's open market operations (because most open market purchases and sales take place in Treasury securities). So do most exchange market interventions by foreign central banks (because most, though nowadays not all, hold a disproportionately large share of their dollar portfolios in Treasury bills compared to the typical private market participant). So do the "window dressing" activities of banks and other private investors that choose to sacrifice a few days' interest differential in order to show atypically large Treasury bill holdings on their year- or even quarter-end financial statements. The effect of each of these distortions is to make movements in the Treasury bill rate less likely to correspond to what matters in financial markets for nonfinancial economic activity than movements in the commerical paper rate.

If the commercial paper rate is in fact the better measure of financial market price information in this context, then using it instead of the Treasury bill rate will make a difference for tests of the information about output movements contained in money (or any other financial quantity variable). Table 5 presents evidence showing that the choice of short-term interest rate does indeed matter in just this way. The table shows F-statistics for tests of the null hypothesis that all of the coefficients on money are zero, and also for (separate) tests of the null hypothesis that all of the coefficients on the interest rate are zero, in Stock-Watson equations for real output. The table shows results based on using the three month Treasury bill rate as the model's short-term interest rate, as in Stock and Watson's work, and alternative results based on using the four-to-six month commercial paper rate. In both cases the sample period ends in December 1985.

Although the F-statistics for the effect of the interest rate on output are uniformly larger for the commerical paper rate than for the Treasury bill rate, in no case does the change render this effect significant at any plausible level. By contrast, which short-term interest rate the model includes strongly affects the significance of the effect of money on output. In Stock and Watson's preferred specification, the effect of money that is easily significant at the .01 level in the presence of the Treasury bill rate is no longer significant even at the .05 level in the presence of the commercial paper rate. In both of the variant specifications, making this substitution renders the effect of money that is easily significant at the .05 level in Stock and Watson's results no longer significant even at the .10 level.

Just as the results presented in Section I show that adding data from 1986

TABLE 5

IMPLICATIONS OF ALTERNATIVE INTEREST RATES IN STOCK-WATSON TESTS, 1960-1985

	Treasury Bills	Commercial Paper
No Time Trend		
F-Statistic for Money	2.45 (.025)	1.36 (.231)
F-Statistic for Interest Rate	.66 (.792)	1.18 (.297)
Linear Time Trend		
F-Statistic for Money	2.96 (.008)	1.72 (.115)
F-Statistic for Interest Rate	.64 (.811)	1.06 (.393)
Linear, Quadratic Time Trends		
F-Statistic for Money	2.47 (.024)	1.47 (.189)
F-Statistic for Interest Rate	.65 (.795)	1.06 (.397)

Note: Numbers in parentheses are marginal significance levels.

The sample period is 1960:2-1985:12.

and 1987 to the sample is subversive of Stock and Watson's findings, the evidence shown here indicates that *even within their own sample* Stock and Watson's findings hinge crucially on the use of the Treasury bill rate (with all of its technical oddities) rather than the commercial paper rate, to represent financial market price information. Not surprisingly, simultaneously extending the sample *and* substituting the commercial paper rate for the Treasury bill rate overwhelms Stock and Watson's positive findings altogether. As Table 6 shows, the F-statistic for the effect of money on output in their preferred specification is then no longer 1.61, with marginal significance level .143, but .96, with marginal significance level .453. The corresponding collapse is just as severe in the two variant specifications.

Although it may be tempting to interpret these results as a straightforward indication that the commercial paper rate is simply superior to the Treasury bill rate in capturing information about financial effects on nonfinancial economic activity, further investigation shows that the relevant interactions may in fact be more subtle. Table 7 presents F-statistics for several tests of an expanded Stock-Watson real output equation in which the Treasury bill rate is replaced by *both* the commercial paper rate *and* the spread between the commercial paper rate and the Treasury bill rate. The table shows results for the same three sample periods as in Table 4, but only for Stock and Watson's preferred specification including the linear time trend. (Corresponding results for the variants with no trend and with both linear and quadratic trends are highly similar.)

In Table 7 once again, the F-statistic testing the effect of money on real output is significant (even at the .10 level) only in the 1960:2-1985:12 sample, and the effect of the commercial paper rate is not significant at any plausible level in both it and the 1960:2-1987:9 sample. By contrast, what is startling

TABLE 6

IMPLICATIONS OF ALTERNATIVE INTEREST RATES IN STOCK-WATSON TESTS, 1960-1987

	Treasury Bills	Commercial Paper
No Time Trend		
F-Statistic for Money	1.03 (.404)	.67 (.669)
F-Statistic for Interest Rate	.79 (.660)	1.75 (.057)
Linear Time Trend		
F-Statistic for Money	1.61 (.143)	.96 (.453)
F-Statistic for Interest Rate	.74 (.713)	1.56 (.102)
Linear, Quadratic Time Trends		
F-Statistic for Money	1.39 (.220)	.87 (.520)
F-Statistic for Interest Rate	.79 (.661)	1.49 (.129)

Note: Numbers in parentheses are marginal significance levels.

The sample period is 1960:2-1987:9.

TABLE 7

F-STATISTICS FOR EXPANDED STOCK-WATSON EQUATION

	1960:2-1979:9	1960:2-1985:12	1960:2-1987:9
F-Statistic for Money	1.02 (.417)	2.51 (.022)	1.49 (.179)
F-Statistic for Interest Rate	1.67 (.077)	.77 (.686)	.98 (.464)
F-Statistic for Spread	3.15 (.0004)	3.53 (.00007)	3.49 (.00008)
F-Statistic for Constraint	2.68 (.002)	3.99 (.00001)	4.37 (.000002)

Note: Values in parentheses are marginal significance levels.

Interest rate is the commercial paper rate.

Spread is the commercial paper rate minus the Treasury bill rate.

Constraint forces coefficients on interest rate and spread to be equal in magnitude and opposite in sign.

is that the spread between the commercial paper rate and the Treasury bill rate is significant at the .001 level or better in all three sample periods. At the same time, the F-statistic for the (separate) null hypothesis that the respective pairs of coefficients on the commercial paper rate and the spread variable are each equal in magnitude and opposite in sign (so that the net result is equivalent to simply including the Treasury bill rate) warrants rejecting this constraint at a very strong significance level in all three sample periods.

These additional results do not contradict the conclusion that, between the Treasury bill rate and the commerical paper rate, the latter is superior for purposes of assessing financial influences on nonfinancial activity, nor do they affect the parallel conclusion that Stock and Watson's finding of a statistically significant effect of money on real output depends on their use of the Treasury bill rate instead of the commerical paper rate. These further results do suggest, however, that the sources of imperfect covariation between these two interest rates -- presumably including an important role for a default premium that varies over time as perceptions of business creditworthiness change -- capture more of the relevant information about what aspects of financial markets matter for the determination of real output than do movements in either interest rate by itself, or fluctuations in money.

III. The Co-Integration of Money and Income

The empirical tests reported in Sections I and II all focus on relationships connecting the growth rate of money (or some other financial aggregate) to the growth rate of income or prices. Formulating these tests in terms of growth rates is appropriate in light of the repeated finding that in fact money, income and prices all move through time in a nonstationary fashion, with no tendency for the respective levels of these variables to return to specific values.[9] By contrast, for some questions of potential importance in the practical conduct of monetary policy, what matters is indeed the relationship between the level of money and the level of income or prices.

The relationship between the respective levels of money and of income or prices is especially relevant in the context of the "base drift" problem that inevitably arises when the central bank uses as an intermediate target a money (or credit) aggregate that is endogenous over short time horizons. In particular, whenever actual money growth has differed from the growth rate targeted ex ante, the central bank must decide whether to "let bygones be bygones" and simply conduct monetary policy so as best to achieve the targeted growth rate thereafter, or, instead, seek to return the chosen aggregate itself to the previously targeted path, thereby offsetting the initial unplanned deviation of actual from targeted money growth by a subsequent, deliberately engineered deviation in the opposite direction.[10] As Walsh (1986) has shown, which of these two strategies is preferable depends on whether whatever disturbance to the money-income (or money-price) relationship has accompanied the original departure from the targeted path is more likely to prove permanent or transitory, and a strategy of offsetting observed deviations only in part will, in general, dominate either one. Offsetting in full all observed deviations of actual from targeted money growth is optimal only if all disturbances to the money-income relationship are transitory.

The answer to the "base drift" dilemma therefore depends on whether the relationship between the respective levels of money and income -- in its simplest and most familiar form, the ratio of money to income, or vice versa -- is stationary. The fact that money and income are both individually nonstationary need not, of course, imply that the ratio of one to the other is also nonstationary. In statistical terms, two series are co-integrated whenever they are individually nonstationary yet there exists a linear combination of the two that is stationary. A stationary money-income ratio therefore means that money and income are co-integrated in logarithms.

An alternative statement of what co-integration implies that is especially useful for applications to questions about monetary policy puts the point in terms of error correction. As Engle and Granger (1987) have shown, if two variables are co-integrated then it is possible to express the relationship between them as an error-correction process in which the change in either variable is a function of current and past deviations, from the equilibrium value, of the appropriately specified linear combination of the two variables' respective levels. For income chosen as the variable that changes in response to disturbances, such a representation of the money-income relationship is

$$A(L)\Delta y_t = \gamma[y_t - (\alpha + \beta m_t)] + u_t \qquad (3)$$

where y and m are again the logarithms of income and money, respectively; A(L) is a polynominal in the lag operator; γ, α and β are scalar coefficients; and u is a disturbance term. Subject to the lags embodied in A(L), (3) implies that any change in (the level of) m ultimately produces a proportional change in (the level of) y. If (3) is a valid description of the money-income relationship, then the level of the money stock is an appropriate intermediate target of monetary policy if the ultimate policy objective is to affect the level of income.

Empirically establishing the presence or absence of co-integration in this case essentially amounts to testing for stationarity the estimated residual from some form of regression of the level of income on the level of money. For example, if the error-correction mechanism in (3) is a valid representation of the adjustment process for y, the disturbance v in the regression

$$y_t = \alpha + \beta m_t + v_t \tag{4}$$

must be stationary.[11] If v is stationary (with equilibrium level equal to zero, because the equation includes an intercept), then y and m are co-integrated in that y will tend to return to the equilibrium value ($\alpha + \beta m$) after any realized disturbance. Alternatively, if v is as likely to increase or decrease from each period's realized value, then y and m have no tendency to return to an equilibrium relationship, and hence are not co-integrated.

The simplest test procedure, proposed by Dickey and Fuller (1979), examines the first-order autocorrelation of the residual from (3), or any other co-integrating regression, by first estimating the secondary regression

$$\hat{v}_t = \rho_o + \rho_1 \hat{v}_{t-1} + e_t \tag{5}$$

where the $\hat{v}$ are fitted values of v, ρ_o and ρ_1 are coefficients to be estimated, and e is a disturbance term, and then using the appropriate t-statistic to test the null hypothesis that ρ_1 equals unity so that y and m are not co-integrated. A significant value of the Dickey-Fuller t-statistic then means that ρ_1 differs from unity; provided that the estimated value of ρ_1 is less than unity, this rejection of the null hypothesis therefore means that v is stationary. Testing v for stationarity in the presence of higher-order autocorrelations requires the use of an alternative procedure like the augmented Dickey-Fuller method, which includes lagged differences of $\hat{v}$ as additional regressors in (5).[12]

Table 8 presents the results of Dickey-Fuller and augmented Dickey-Fuller tests for co-integration between nominal income and each of several financial aggregates, based on the co-integrating equation (4), for each of three sample periods. The Dickey-Fuller statistic (DF) is not strictly valid in the presence of higher-order autocorrelation. The augmented Dickey-Fuller statistic (ADF) is always valid, but it may have lower power against the null hypothesis of no co-integration in the absence of higher-order autocorrelation. In each case the table reports both statistics, and indicates with parentheses which is less appropriate.[13]

For the sample ending just before the introduction of new monetary policy procedures in 1979, the evidence suggests that M2 and credit, and perhaps the monetary base as well, were each co-integrated with income. (It is interesting that, even for the sample before 1980, there is no evidence of co-integration between M1 and income.) The Dickey-Fuller statistic for the credit equation warrants rejecting the null hypothesis of no co-integration at the .01 significance level, as do the augmented Dickey-Fuller statistics for both the credit equation and the M2 equation. The addition of data through mid 1982, to incorporate the period when the Federal Reserve was employing its new monetary policy procedures, weakens these results so that they are significant merely at the .05 level. Extending the sample through 1987:III eliminates these positive results altogether, except for one statistic (out of ten) that remains significant at the .10 level.[14]

TABLE 8

DICKEY-FULLER STATISTICS FOR TESTS OF CO-INTEGRATION

	Statistic	1959:I-1979:III	1959:I-1982:II	1959:I-1987:III
Monetary Base	DF	-3.22*	-3.21*	(-0.26)
	ADF	(-1.77)	(-1.96)	-0.24
M1	DF	(-2.64)	(-2.92)	(1.48)
	ADF	-1.57	-1.74	-0.34
M2	DF	(-1.81)	(-2.29)	(-1.80)
	ADF	-3.85***	-3.49**	-3.01*
Credit	DF	-4.11***	-3.44**	(1.78)
	ADF	(-3.95***)	(-3.28**)	-0.08

Note: DF indicates Dickey-Fuller statistic.

ADF indicates augmented Dickey-Fuller statistic.

* Significant at .10 level
** Significant at .05 level
*** Significant at .01 level

It is always possible, of course, that money (or credit, or the monetary base) may in fact be co-integrated with income, but with a co-integrating relationship different from (4). Tables 9 and 10 therefore report the results of analogous tests based on the co-integrating equations

$$y_t = \beta m_t + \ell n(\alpha + \phi t) + v_t \tag{6}$$

and

$$y_t - m_t = \ell n(\alpha + \phi t + v_t) \tag{7}$$

respectively, where in each case α is a scalar coefficient. Here (6) allows fo a trend in the money-income relationship -- for example, to accommodate what used to be regarded as a stable trend, approximating 3% per annum, in the relationship between income and M1 -- while (7) treats v as a disturbance to th money-income ratio rather than its logarithm. In neither case, however, do the results differ appreciably from those reported in Table 8 based on the simpler co-integrating equation. Once again, the evidence supporting co-integration before 1980 refers mostly to M2 and credit (and not at all to M1), and there is no such evidence for the sample extended to include the 1980s.

Unlike before the 1980s, therefore, there is no longer evidence to support the claim that M2, credit, or the monetary base is co-integrated with income. If for some reason the central bank happens to be conducting monetary policy by using any of these variables as an intermediate target, therefore, there is no longer evidence to support the injunction to resist the "base drift" that arise from past failures to achieve the targeted growth rate.

TABLE 9

FURTHER TESTS FOR CO-INTEGRATION: ERROR WITH TREND

	Statistic	1959:I-1979:III	1959:I-1982:II	1959:I-1987:III
Monetary Base	DF	-2.90	-3.03*	(-0.13)
	ADF	(-1.80)	(-2.04)	-0.22
M1	DF	(-2.54)	(-2.87)	(1.49)
	ADF	-1.53	-1.61	-0.34
M2	DF	(-2.02)	(-2.28)	(-1.62)
	ADF	-3.67**	-3.40**	-2.69
Credit	DF	-3.60**	-3.28*	(1.80)
	ADF	(-2.97*)	(-3.02*)	0.09

Note: DF indicates Dickey-Fuller statistic.

ADF indicates augmented Dickey-Fuller statistic.

* Significant at .10 level
** Significant at .05 level
*** Significant at .01 level

TABLE 10

FURTHER TESTS FOR CO-INTEGRATION: ERROR TO LEVEL

	Statistic	1959:I-1979:III	1959:I-1982:II	1959:I-1987:III
Monetary Base	DF	-3.04*	-3.10*	(-0.46)
	ADF	(-1.68)	(-1.77)	0.01
M1	DF	(-2.68)	(-2.60)	(1.08)
	ADF	-1.46	-1.30	-0.20
M2	DF	(-1.74)	(-2.22)	(-1.81)
	ADF	-3.72**	-3.38**	-2.98*
Credit	DF	-4.06**	-3.31*	(2.56)
	ADF	(-3.84***)	(-3.10*)	0.08

Note: DF indicates Dickey-Fuller statistic.

ADF indicates augmented Dickey-Fuller statistic.

* Significant at .10 level
** Significant at .05 level
*** Significant at .01 level

IV. Summary of Conclusions and Policy Implications

The empirical findings presented in this paper consistently show that evidence based on the most recent U.S. experience does not indicate a close or reliable relationship between money and nonfinancial economic activity. First, merely extending the analysis to include data from the 1980s sharply weakens the time-series evidence from prior periods showing that such relationships existed between money and nominal income, or between money and either real income or prices considered separately. Focusing on data from 1970 onward destroys this evidence altogether. The deterioration of the evidence supporting a relationship to either real or nominal income, or to prices, appears not just for M1 but for other monetary aggregates and for credit as well.

Second, the finding that particular forms of time-series experiments still showed a significant role for money in affecting real output through 1985 not only becomes weaker on the inclusion of data from 1986 and 1987 but also, even for data through 1985 only, turns out to depend on the use in the analysis of a particular short-term interest rate, the Treasury bill rate. Using instead the commercial paper rate, which apparently is superior in capturing the information in financial prices that matters for the determination of real output, also strongly weakens this prior finding. Simultaneously using the commerical paper rate and including data through 1987 destroys it altogether.

Third, extending the analysis through 1987 also destroys the time-series evidence from earlier periods showing that money and income are co-integrated. As in the first set of conclusions, this deterioration in the 1980s applies not just to M1 but also to other monetary aggregates and to credit.

These results bear strongly negative implications for monetary policy frameworks that focus the design and implementation of policy on money (or credit) in any formally systematic way. There is no longer empirical evidence to support the existence of relationships that would warrant making monetary policy in such ways. The point is not just that the money-income relationship does not satisfy the stringent conditions that would be required to render optimal the strict use of money as an intermediate target. More importantly, there is no evidence to show that fluctuations in money contain any information about subsequent movements in income or prices. Further, even if the central bank did choose for some reason to base monetary policy on the use of money as an intermediate target, in the absence of evidence indicating that money and income are co-integrated there would be no grounds on which to resist "base drift."

The paper's one finding with potentially positive implications for monetary policy is that the spread between the commerical paper rate and the Treasury bill rate does contain information about future movements in real income, information that is highly significant regardless of the sample period under investigation. It is difficult to imagine that the Federal Reserve could use this interest rate spread as an intermediate policy target, and doubtful that the relationships found here would continue to hold if it did. By contrast, in a world in which previously standard financial quantities can no longer serve as policy information variables because they no longer contain information about the macroeconomic outcomes that monetary policy seeks to affect, policymakers must somehow fill the resulting vacuum by exploiting information from wherever they happen to find it.

Footnotes

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1. See, for example, the literature surveyed by Friedman (forthcoming).

2. See, for example, the literature surveyed by McCallum (1985).

3. Kareken et al. (1973) first formally introduced the information variable concept into the analysis of monetary policy. See Friedman (1975) for a formal analysis of the intermediate target variable procedure.

4. The monetary base and the three "M's" are based on the conventional Federal Reserve Board definitions. Credit is the outstanding indebtedness of domestic nonfinancial borrowers. Income is gross national product. (Substituting domestic absorption for gross national product does not systematically change the results reported here, or in most of the tables introduced below; see, however, footnote 14.) All data are seasonally adjusted.

5. The sensitivity of the results of such tests to these and other aspects of the underlying specification are well known. See, for example, Zellner (1985).

6. The same is true for credit. M2 is significant in some specifications of the equation for real income (though not for prices) for the 1960:II-1987:II sample, but not for the 1970:I-1987:II sample.

7. See Friedman (1984) for a comparative treatment of long-versus short-term interest rates, and Eichenbaum and Singleton (1986) for a discussion of the use of equity prices, in this context.

8. Eichenbaum and Singleton were incorrect in stating (p. 125) that Sims had used the Treasury bill rate; see Sims (p. 252).

9. See, for example, Nelson and Plosser (1982). In more precise statistical terms, the work "nonstationary" here means that the variance of a stochastic time series process grows over time without bound; see, for example, Fuller (1976).

10. The origin of the label "base drift" for this problem was the complaint, often voiced during the late 1970s, that the Federal Reserve System was accommodating rising inflation by pursuing a "bygones" strategy in which the targeted rate of money growth was low each year but actual money growth on a multi-year basis was high because, with repeated upward errors, each year's <u>target</u> growth was calibrated from the higher "base" level resulting from the previous year's <u>actual</u> growth.

11. Specifying the relationship in terms of a constant equilibrium value for the money-income ratio simply corresponds to setting $\beta = 1$.

12. As is well known, the distribution of the resulting test statistic is highly non-normal, and so critical values are typically calculated from Monte Carlo simulations. See Engle and Granger (1987) for a discussion of these and other plausible test statistics for the presence of co-integration, and for computation of critical values.

13. Significance levels are indicated according to critical values computed by Engle and Granger (1987) for a time series of length 100, and with lag length 4 in the case of the adjusted Dickey-Fuller test. As Engle and Granger demonstrated, tests of the null hypothesis of no co-integration ($\rho_1 = 1$) tend to display low power against alternatives corresponding to co-integration, such as $\rho_1 = .95$. For example, with $\rho_1 = .9$ and $N = 100$ the Dickey-Fuller test at the .05 level would, on average, reject the "no co-integration" null hypothesis only 15% of the time. For the purposes of monetary policy, however -- including in particular the question of what to do about "base drift" -- it matters little whether shocks to the money-income relationship are truly permanent ($\rho_1 = 1$) or only very highly persistent. Values of ρ_1 equal to .95 or .99, for example, still imply shocks with half-lives equal to 13.5 quarters or 69 quarters, respectively.

14. If y is defined as domestic absorption instead of gross national product, the ADF statistic for M2 is - 3.76, significant at the .01 level.

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