Output Fluctuations and Monetary Shocks: Evidence from Colombia

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Output Fluctuations and Monetary Shocks

Evidence from Colombia

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Using annual data for Colombia over the last 30 years, we test opposing theories that explain macroeconomic fluctuations: the neoclassical synthesis, which posits that in the presence of temporary price rigidity an unanticipated monetary expansion produces output gains that erode over time with increases in the price level; and an alternative explanation, which focuses on "real" technological or preference shocks as the sources of output changes. Coefficients from this system are used to examine the long-run neutrality of nominal quantities with respect to permanent movements in the money stock and the short-run sensitivity of output to inflation. (JEL E3)

Any macroeconomic model makes a judgment—explicit or implicit—concerning the correlations among money, income, and prices. The neoclassical synthesis, represented by models combining forward-looking agents planning their spending decisions in the face of temporarily rigid prices, predicts that an unexpected monetary relaxation will be associated with an elevated level of real output at first, but that the output gain erodes over time with increases in the price level.[1] As an

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[1] The reasons for the sluggishness of prices include nominal contracting, as in Calvo (1983) and Calvo and Vegh (1990b), adjustment costs, as in Mussa (1981), and asynchronous price setting, as in Blanchard (1990).

alternative approach, an influential group of researchers have formulated nonmonetary frameworks that explain observed correlations among real variables in terms of real impulses, such as technological or preference shocks. Money enters at the periphery of the picture, with nominal quantities settling at levels reflecting an endogenous provision of money balances.[2]

This paper, taking advantage of a new battery of econometric techniques, tests these opposing macroeconomic theories against the annual data for Colombia over the last 30 years. Colombia, with a history of moderate to high rates of price increase, offers a range of variation of the basic time series without the pathologies inherent in hyperinflations. The basic strategy is to estimate a compact reduced-form system explaining the predictable comovements among the nominal money stock, the price level, and real income. The coefficients from this system are used to examine two basic propositions: the long-run neutrality of nominal quantities with respect to permanent movements in the nominal stock of money; and the more short-run sensitivity of output to inflation (which proved troublesome for Barro (1979)). The unexplained portion of the movement in these variables is then given a structural interpretation by the imposition of identifying assumptions on the pattern of correlation among the residuals, as in Adams (1990) and Blanchard (1989), thus providing some insight into the nature of the underlying shocks and the economy's propagation mechanism. Our goal is not to impose strict theoretical priors on the macroeconomic time series, but rather to capture the key set of empirical regularities that any reasonable theory, at a minimum, must capture.

Additionally, prescriptions concerning monetary policy are often integral to the adjustment programs undertaken by many developing countries, particularly small open economies beset by high inflation. The consequences of those disinflation efforts importantly depend on the macroeconomic structure that underlies the correlations among money, income, and prices. Reducing money growth to combat entrenched inflation is costless to the extent that there are no effects on output, real rates of return, and the real exchange rate. Potentially, this econometric apparatus can quantify the unintended consequences of such disinflationary policies.

The empirical linkage between monetary policy and inflation has been

[2] Examples of this work include Kydland and Prescott (1982) and King and Plosser (1984, 1986). For a critical survey, see the summer 1989 issue of the *Journal of Economic Perspectives,* in particular, Plosser (1989) and Mankiw (1989).

documented for Colombia by Barro (1979), Clavijo (1987), Clavijo and Gomez (1988), Edwards (1984), Fernandez Riva (1988), and Leiderman (1984), among others. These papers commonly find evidence of a positive and statistically significant relationship between monetary growth and inflation. Indeed, a majority indicate the presence of a causal linkage running from money to output and prices, thus favoring the neoclassical explanation of macroeconomic fluctuations. However, these studies have not typically examined the time-series behavior of the variables of interest. There has been a growing realization that neglecting to account for basic time-series properties of the variables that enter a behavioral relationship can cloud inference.

Granger and Newbold (1974) showed nearly 20 years ago that an ordinary-least-squares regression between two variables that behave as random walks with drift is bound to find a measure of "significance," independent of any deeper behavioral link. That intuition has been codified with a set of tests to determine if a series behaves like a random walk, as well as new limiting distributions to define a level of statistical significance among such variables (including the important work of Dickey and Fuller (1981), Engle and Granger (1987), and Phillips (1987), ably summarized in Campbell and Perron (1991)). Using U.S. data, Stock and Watson (1989) have shown that much of the disagreement among results concerning the causal linkage between money and prices can be traced to differing specifications of the underlying variables. Their moral is that care must be taken at the outset in defining the unit of observation and the basic specification-that is, whether to use levels or rates of change of each variable appearing in a regression and whether that regression should include a constant and time trend.

The starting point of our analysis is to establish the time-series properties of the variables of interest. Subsequently, we follow Leiderman (1984) and Clavijo (1987) by estimating an unrestricted reduced form to assess the interrelationships among inflation, output growth, wage changes, and the policy variables-various measures of the nominal money stock, the exchange rate, and the minimum wage. The resulting dynamic explanation of the inflation process resembles, in many ways, the theoretical derivation of Khan (1980). The unexplained remainder provides measures of the contemporaneous correlation among these variables and permits a more detailed investigation of the sources of shocks than has previously been available.

This technique also can bear on the debate over the lever through which monetary policy influences the economy. Traditionally, researchers assign one instrument to the central bank, modeling policy as working by varying the stock of a money or credit aggregate or by pegging an interest rate. Recently, Calvo and Vegh (1990a, 1990b) have suggested that when assets are imperfect substitutes, the conduct of monetary policy can have elements of both money stock and interest rate rules. In our framework, this reduces to an empirical issue concerning the source of the contemporaneous variation in money and interest rates.

The next section details the specification search, first examining the time-series properties of an array of macroeconomic variables. From that set, varying combinations of explanatory variables are considered to arrive at a compact, reduced-form model of the Colombian economy. This simple framework yields some insights as to the systematic comovement of money and inflation. However, it is not a complete system until, in Section II, the observed contemporaneous correlation is attributed to primitive shocks. That section also examines alternative decompositions to reflect the range of opinions in the theoretical literature. Section III offers concluding comments.

I. Time-Series Properties of Inflation and Money Growth

Most economic time series exhibit substantial comovement, but for policy analysis it is critical to distinguish between a correlation that arises from a shared trend and one associated with an underlying causal relationship. Granger and Newbold (1974) showed that when the dependent and independent variables have unit roots, traditional estimation methods using observations on the levels of those variables will likely find a statistically significant relationship, even absent a meaningful "economic" linkage. For example, the simplest case of a process with a unit root is the random walk, written here for the variable x_t:

$$x_t = \alpha + \rho x_{t-1} + e_t, \tag{1}$$

where e_t is an independent disturbance, and ρ equals unity. Since ρ equals unity, a shock to e_t is incorporated permanently into the level of x_t. The constant, α, represents a drift, which allows for a secular movement in x_t. Granger and Newbold's insight was that two variables that behaved like equation (1) will be correlated, independent of any common element to their respective shocks.[3]

To avoid erroneous inference, the data were subjected to a variety of tests to establish their univariate time-series behavior in order to determine the basic unit of observation-that is, whether the subsequent

[3] Ohanian (1988) generalizes the problem to the multivariate setting considered in the paper..

estimation should use the level or first difference of each time series. The tests include the Dickey-Fuller (DF) and augmented Dickey-Fuller (ADF), explained in Engle and Granger (1987), Phillips (1987), and Campbell and Perron (1991), and are given in Table 1. In effect, these statistics test whether p equals unity, which implies that the steady-state level of x_c (as well as its variance) is not well defined, or whether p is less than unity, which implies that x_t gravitates toward some steady-state level. In practice, each statistic tests for significant deviations from the assumed null hypothesis of nonstationary behavior. Subtracting x_{c-1}

Table 1. *Time-Series Properties of the Macroeconomic Variables, 1960–87*

	With No Drift		With Drift	
Variable	DF	ADF	DF	ADF
		Tests for one unit root		
Money (M1)	1.56	-0.17	-0.04	-0.39
Prices (CPI)	1.91	-0.28	-0.25	-1.11
Prices (WPI)	2.02	-0.10	-0.38	-1.42
World coffee prices	-1.11	-1.38	-1.63	-1.61
Exchange rate	2.73	0.81	-0.07	-1.53
Wages (manufacturing)	1.46	-0.41	-0.11	-1.16
Minimum wage	1.43	-0.37	-0.76	-1.19
Real GDP	0.35	0.21	-0.5	-2.46
Nominal interest rate	-1.87	-1.17	-3.62	-1.75
Real interest rate	-3.01	-2.30	-3.65	-2.46
		Tests for two unit roots		
Money (M1)	-3.76	-1.33	-5.47	-2.72
Prices (CPI)	-3.37	-1.56	-4.64	-2.77
Prices (WPI)	-2.46	-1.98	-3.36	-3.46
World coffee prices	-4.61	-2.21	-4.58	-2.18
Exchange rate	-3.17	-2.57	-3.48	-2.94
Wages (manufacturing)	-2.89	-1.89	-3.14	-2.1
Minimum wage	-3.75	-3.01	-3.89	-3.26
Real GDP	-3.43	-2.49	-3.51	-2.55
Nominal interest rate	-8.88	-2.44	-8.89	-2.46
Real interest rate	-7.02	-3.51	-6.93	-3.38

Critical values·

	No Drift	*Drift*
5 percent	-2.97	-3.59
10 percent	-2.61	-3.47

Note: DF denotes the Dickey-Fuller test; ADF denotes the augmented Dickey-Fuller Test.

·25 observations.

from both sides of equation (1) and denoting the first difference of a variable by Δ:

$$\Delta x_t = \alpha + (\rho - 1)x_{t-1} + e_t \qquad (1')$$

nonstationarity would be associated with a zero coefficient on the lagged level of the variable x_{t-1}. Stationarity ($\rho < 1$) translates into a significant negative dependence of the differenced variable on its lagged level when equation (1') is treated as a regression exercise. Such dependence can be calculated by a simple *t-test*. However, a complication arises because the form and distribution of test statistics depend on the exact null hypothesis, varying according to the presence or absence of a drift term (that is, what is assumed about the coefficient α).

The first two columns of the table record statistics based on the assumption that there is no drift, while the last two columns posit a significant drift. The top panel tests for the presence of a single unit root, and the bottom panel tests for the presence of two unit roots. Critical values (which are the same for the DF and ADF statistics) are given at the bottom of the table for the no-drift and drift cases. As is clear, in the upper panel, except for interest rates, no test statistic falls beyond the critical values. Thus, the evidence suggests that real and nominal quantities in Colombia have one unit root; that is, each x_t behaves like equation (1), requiring that it be differenced to achieve stationarity. Further, according to the DF and ADF tests in the bottom panel, the evidence suggests that first differencing is sufficient, or that the variables do not have two unit roots. However, interest rates are the important exception. These tests indicate that the real interest rate and, most likely, the nominal interest rate may be stationary time series. As a result, measures of the interest rate will appear in levels, while all other variables appear as rates of change.

The Specification Search

The goal is to explain the joint movement of the price level, real output, and the nominal stock of money, in the expectation that this explanation will shed light on the relative merits of competing macroeconomic theories. However, researchers have found that observed relationships depend importantly on the other variables included in the estimation scheme. For example, using U.S. data, Sims (1980) found that movements in the money stock reliably preceded movements in output. But, after he included a nominal interest rate in his system, that explanatory power evaporated. Our strategy is to cast a wide net at first, estimating systems purporting to explain a long list of variables. We then winnow that list as the data dictate, ending with a compact system relating money, income, prices, and whatever else may be needed.

Ideally, a structural model would link observations on the set of endogenous variables in terms of their own current and lagged behavior, as well as the exogenous variables. In generic terms, such a model could be written in matrix form as

$$A\begin{bmatrix}\Delta M_t\\ \Delta y_t\\ \Delta P_t\end{bmatrix} = B(L)\begin{bmatrix}\Delta M_{t-1}\\ \Delta y_{t-1}\\ \Delta P_{t-1}\end{bmatrix} + C(L)\begin{bmatrix}\Delta X1_t\\ \Delta X2_t\end{bmatrix} + \begin{bmatrix}e_t^M\\ e_t^y\\ e_t^P\end{bmatrix}, \tag{2}$$

where A is a 3 x 3 matrix of coefficients with 1's on the diagonal; $B(L)$ is a 3 x 3 matrix of polynomials in the lag operator, which shifts a series back in time—that is, $Lw_t = w_{t-1}$; and $C(L)$ is a 3 x 2 matrix of lag polynomials. The variables $X1$ and $X2$ stand for explanatory variables found to be significant in the specification search, and the Δ's denote the first difference of a variable, which the univariate results of the previous section suggested were appropriate. Equation (2) can be solved to find a set of three equations in terms of predetermined variables:

$$\begin{bmatrix}\Delta M_t\\ \Delta y_t\\ \Delta P_t\end{bmatrix} = A^{-1}B(L)\begin{bmatrix}\Delta M_{t-1}\\ \Delta y_{t-1}\\ \Delta P_{t-1}\end{bmatrix} + A^{-1}C(L)\begin{bmatrix}\Delta X1_t\\ \Delta X2_t\end{bmatrix} + \begin{bmatrix}u_t^M\\ u_t^y\\ u_t^P\end{bmatrix}, \tag{3}$$

where the vector of reduced-form residuals, $u_t' = (u_t^M, u_t^y, u_t^P)$, depends on the structural errors, $e_t' = (e_t^M, e_t^y, e_t^P)$, and the relationship among the endogenous variables, A. Specifically:

$$u_t = A^{-1}e_t. \tag{4}$$

This reduced form can be estimated by ordinary least squares, yielding consistent predictions and estimates of the compound terms, $B(L)A^{-1}$ and $C(L)A^{-1}$. A researcher concerned about the structural parameters—the individual elements of A, B, and C—then needs to solve the identification problem. Identification requires using economic theory (and common sense) to limit the number of parameters being estimated. Typically, this takes the form of exclusion restrictions, or the assumption that not every variable appears in every equation, placing zeros in the coefficient matrices. With enough a priori restrictions, the individual elements of the parameter matrices can be calculated, given estimates of the reduced form. However, a researcher confident about those identifying restrictions should impose them at the outset, since that information permits more efficient estimation techniques. Indeed, much of the agenda in econometrics until the 1970s was filled with formalizing the identification problem and detailing efficient means of estimating systems given by equation (2).

However, since there are competing paradigms to be tested with vastly different implications for the structural parameters, we impose at the outset as few priors as possible. The result is that efficiency is traded off in favor of flexibility. This "unstructured" approach finds support in the failure of large-scale models to explain the sea change of the 1970s and Lucas's theoretical explanation of why that failure should not have been surprising. Vector autoregressions (VARs) are the simple alternative to the increasingly complicated-and sometimes arbitrary-use of exclusion restrictions, and are particularly attractive to researchers unattached to a specific economic theory. Essentially, the VAR methodology advocates manipulating estimates of the reduced-form (equation (3», to characterize the comovements of the endogenous variables. The presence of lagged variables implies that a shock to one equation potentially traces complicated dynamics in all three variables. Also, forecast errors in one equation over time help to explain the variability of prices, output, and money.

Such VARs were used as a tool to analyze the dynamic responses among output, prices, various monetary aggregates, interest rates, the exchange rate, both general wages and the minimum wage, and the price of coffee.[4] All variables were treated as potentially endogenous. This step in the specification search allowed the data to determine which set of variables would define our macroeconomic framework and determined the extent to which each policy variable was subject to feedback from other variables-that is, how truly "exogenous" those policy variables were.[5] The data also determined the optimum lag length. No priors were imposed on the lag profile and a variety of selection criteria were calculated.

The major facts that emerged from these regressions, which are omitted to conserve on space, were as follows.

- Leiderman (1984) found in a system consisting of prices, money, and output that no lagged variables were significant in explaining the dynamic behavior of M1-suggesting exogeneity in the Granger sense. Broadening the system to include the interest rate, exchange rate, and wages did not alter his result..
- There was no evidence of a lagged relationship between the inflation rate and export coffee prices. (There was also no evidence of a contem-

4 The variables considered are listed in the Appendix.

5 In our case the policy variables considered were the monetary aggregates, the nominal interest rate, and the nominal exchange rate.

poraneous relationship.) This finding runs counter to the positive relationship posited by Edwards (1984), who argued that a boom in coffee prices would lead to an accumulation of reserves, which, unless sterilized, would result in faster money growth and inflation.

• Past fluctuations in inflation, money growth, as well as its own history, helped predict the exchange rate. This evidence of the "endogeneity" of the nominal exchange rate in Colombia's crawling peg system suggests a (possibly time-varying) feedback rule on the part of policymakers, or the presence of a policy that targets the real exchange rate.[6]

• The inertia in wages was greater than the inertia in prices. Once money is included in the system, lagged values of inflation were insignificant in the price equation. Wage dynamics, however, continue to depend on their own history, as well as on other lagged nominal variables (that is, money and the exchange rate).

• Our results using annual data on rates of change parallel those of Sims (1980), who studied level data at a higher frequency for the United States. Movements in money reliably preceded movements in output but, after including a nominal interest rate in the system, much of that explanatory power disappears.

The Reduced-Form Model

In the end, we settled on a six-variable system using the growth rates of the narrow monetary aggregate, M1, real income (GDP), consumer prices (CPI), average wages in manufacturing, the nominal exchange rate, and the level of the nominal interest rate. Because there is no obvious criterion for selecting lag length, Table 2 reports the four mea-

Table 2. *Criteria for Selecting Lag Length*

	Number of Lags			
Model Criteria	0	1	2	3
Akaike	18.55	14.84	12.16	<u>9.02</u>
Schwarz	<u>18.55</u>	19.12	20.73	21.87
Log(FPE)	25.22	21.44	18.58	<u>15.07</u>
Hannan and Quinn	18.55	<u>17.93</u>	18.35	18.31

Note: The model selected by each criterion is underlined.

[6] For a model that illustrates the endogeneity of the nominal exchange rate and its response to a variety of shocks under a policy that targets the real exchange rate, see Montiel and Ostry (1991; this issue).

Table 3. *Summary of Results: Model Estimated from 1960–87*

Test Statistic	Money	Real GDP	Prices	Wages	Interest Rate	Exchange Rate
Goodness-of-fit statistics						
R^2	0.355	0.399	0.5	0.641	0.687	0.528
SEE	4.82	1.64	6.06	4.38	6.4	7.15
Tests of exclusion restrictions						
Money	0.398	0.705	4.083-	8.609-	1.762	2.788
Real GDP	0.27	0.7	0.456	1.561	0.278	1.002
Prices	0.714	1.356	0.284	2.574	1.974	8.686-
Wages	0.41	2.286	7.706-	12.164-	4.117-	0.931
Interest rate	0.034	3.659-	0.133	0.758	9.715-	1.793
Exchange rate	1.751	1.061	0.542	4.939-	0.0	5.525-
Properties of the reduced-form error						
$q(14)$	12.77	37.746-	13.006	10.528	8.826	14.189
Skewness	0.352	0.52	-0.173	0.034	-0.149	0.607
Kurtosis	-1.254	0.851	-0.774	-0.075	-0.29	-0.022
Correlation among the reduced-form errors						
Money	1.0	0.21	0.38	0.02	0.39	-0.26
Real GDP		1.0	-0.22	-0.17	-0.24	-0.42
Prices			1.0	0.14	0.78	0.26
Wages				1.0	0.03	0.17
Interest rate					1.0	0.29
Exchange rate						1.0

Note: The model was estimated with 1 lag and 21 degrees of freedom per equation. An asterisk denotes a departure from the **null** hypothesis that is significant at the 10 percent level; R^2 is the coefficient of determination, and SEE is the standard error of the equation.

sures used frequently in this literature: the Akaike, Schwarz, and Hannan and Quinn criteria, and the logarithm of the final prediction error (FPE).[7] All of these statistics are concerned with minimizing the value of the determinant of the covariance matrix of the residuals, but differ according to the penalty attached to increasing the number of estimated parameters. Not surprisingly, these measures offer conflicting advice, varying from the harshest critic of free parameters (the Schwarz criterion), which suggests using only a constant term in the estimation, to the Akaike and FPE criteria, which would allow us to consume almost all the available degrees of freedom. Given the limited sample, we opted for a parsimonious specification, using a constant and one lag of each variable.

The results of this estimation are summarized in Table 3 (see also Table 9 in the Appendix), with each column representing an equation ofthe model.. As the entries in the first panel attest, the model explains a significant fraction of the variability of the series, doing best for inertial macro variables, such as wage growth and the policy-controlled nominal interest rate, surprisingly well for the change in the exchange rate, and least well for growth of the nominal money stock. The latter may be witness to the varying pace of financial innovation, as well as to changes in the policy goals of the Colombian authorities over the course of the sample period.

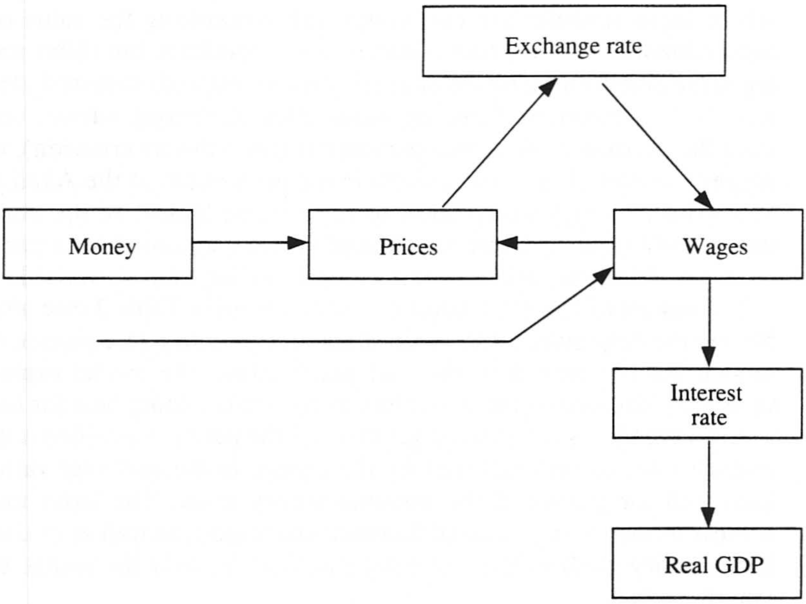
The second panel presents *F-tests* of exclusion restrictions, where the (i,j) element tests whether the ith variable appears in the jth equation. For example, reading down the third column detailing results for the consumer price index (CPI) relationship, only lagged changes in money and wage growth have any significant impact on inflation. The pattern of significance among the variables determines how shocks to anyone equation are propagated through the dynamic system.

Figure 1 describes these relationships graphically. Each box represents one variable in the system, with an arrow showing the direction of a statistically significant impact.. For example, the three lines connected to the CPI box show that the growth rates of Ml and wages enter importantly in the CPI equation (those arrows point inward), while inflation affects the rate of change in the exchange rate (that arrow points outward).

The figure suggests three important dynamic properties of the Colombian economy. First, since movements in Ml predictably influence other variables, but no previous movements in other variables predictably influence Ml, the nominal money stock is exogenous in the Granger

[7] Lutkepohl (1985) provides simulation evidence on the efficacy of these criteria.

Figure 1. *Causal Relationships Among the Variables*



sense. Thus, this nominal aggregate predictably influences domestic nominal magnitudes-prices, wages, and the exchange rate. Second, the significant feedback among nominal magnitudes, the changes in consumer prices, wages, and the exchange rate, may produce complicated dynamics. Any perturbation to one of those relationships will feed through the entire price sector, suggesting a sluggishness in pricing decisions familiar in the literature on the wage-price spiral, a result that is not surprising, given the pervasiveness of long-lived contracts in the Colombian labor market where the average contract length in the private sector is two years. Third, income appears at the bottom of any Granger-causal ranking, because it influences no other variable, even as it is influenced by the nominal interest rate. Thus, any comovement between income and money predicted by this model, for example, would not arise from the systematic effect of past movements in income on Ml, casting some doubt on the reverse-causation argument of the real business cycle theorists, at least for the Colombian economy.

The flow chart in Figure 1 speaks only to the statistical significance of the relationships among the variables, not to the magnitudes of the responses. Since money growth appears exogenous in the system, we can consider any arbitrary path for Ml. The exercise reported in Table 4

Table 4. *Monetary Policy Multipliers Implied by the Estimated Coefficients*
(Percent difference of level of each variable from baseline)

Years after Change	Money	Real GDP	Prices	Wages	Interest Rate[a]	Exchange Rate
			1 percent increase in MI			
1	1	0.06	0.55	0.58	0.38	0.54
3	1	0.02	0.93	0.58	0.14	0.21
9	1	-0.08	1.05	0.85	0.03	0.55
			25 basis point increase in interest rate lasting one year			
1	0.09	-0.31	0.22	0.38	0	0.95
3	0.52	-0.30	0.70	0.63	0	1.94
9	0.57	-0.24	0.80	0.57	0	1.48

[a] Percentage point difference from baseline.

examines a permanent 1 percent increase in the money stock, calculated by feeding a 1 percentage point increase in money growth lasting one year through to the other five variables in the system. In this example, we have, but did not use, an equation explaining money growth over time, but, instead, enforced an exogenous path for money. The resulting effects on rates of change were then cumulated to calculate the multipliers reported in the table. Those multipliers suggest approximate long-run monetary neutrality, as income is virtually unchanged, while the domestic price level increases about 1 percent, after a permanent 1 percent increase in the level of MI. However, this exercise also suggests that long-lived external consequences are felt by domestic workers. The nominal exchange rate depreciates by half the increase in the CPI, and, invoking the small-country assumption that there is no feedback to foreign prices, there is a permanent real exchange rate appreciation. Thus, a change in the nominal exchange rate is also reflected in a change in the real exchange rate, similar to Mussa's findings in his exhaustive examination of nominal and real exchange rates in developing countries (Mussa (1986)). More recently, Lizondo and Montiel (1991) have argued that a nominal shock (in their case a nominal devaluation) may be nonneutral even in the long run if the fiscal adjustment that accompanies the shock changes the aggregate demand for nontraded goods. With foreign competitiveness impaired, domestic workers see a decline in their real wage, as the nominal wage increases by only about 85 percent of the increase in domestic prices.

The bottom panel of Table 4 illustrates the effects of a 25 basis point increase in the nominal interest rate lasting one year, a temporary rate-of-return shock that has effects that are similar in magnitude to those seen in the upper panel. With inflation largely predetermined at a point in time, the increase is, in effect, a real one. In contrast to the monetary shock, the interest rate increase has larger and longer-lived output consequences. Output falls most over the near term, but even nine years after the shock, output remains below its initial level. With the nominal wage adjusting more gradually than other prices, the real wage first rises (possibly contributing to the output loss), then falls. Prices are higher. Indeed, the price level increases by more than the nominal money stock, lowering real balances in line with the lower level of real output. The foreign sector proves more puzzling in this simulation: Both the nominal and real exchange rate depreciate. This result may simply be highlighting the limitations of these simulation exercises, as they are drawn by the patterns of temporal significance among the variables. If the exchange rate is as influenced by contemporaneous factors as it is by lagged determinants, then we may well see significant revisions to these results. We next examine the within-year relationships among the variables to detail a complete description of temporal and contemporaneous effects.

II. A "Structural" Model of the Colombian Economy

The multiplier results of the previous section should not be interpreted too finely, as they reflect a partial solution to the model, using five of the six equations and making no effort to explain the substantial contemporaneous correlation among the prediction errors. Indeed, returning to Table 3, the fourth panel shows that errors in some of the equations share a high degree of common movement. The structural model gives a good reason for this correlation, namely, equation (4). Reduced-form errors will be correlated to the extent that endogenous variables appear in more than one equation of the structural system. The notion of a forecast error, the heart of the VAR methodology, becomes problematic. A u^M shock, for example, could represent either an independent monetary disturbance or the within-period monetary response to an income or price shock.

In the end, the econometrician cannot escape using theory. In the VAR world, this is addressed with a "causal ordering," or a set of assumptions that allow the researcher to parse the observed contemporaneous correlation in the reduced-form errors to unobserved structural errors. In our price-output-money example, the structural errors could be reclaimed by assuming

$$u_t^M = e_t^M$$

$$u_t^Y = f_1 e_t^M + e_t^y$$
$$u_t^P = f_2 e_t^M + f_3 e_t^y + e_t^P,$$

where the *f's* are constants. This imposes the theoretical restriction that money shocks are independent, output shocks respond to within-period money shocks, and inflation owes its variability to both money and output shocks. Alternatively, an accommodative money rule might imply

$$u_t^M = e_t^M + f_1 e_t^Y + f_2 e_t^P$$
$$u_t^y = e_t^y$$
$$u_t^P = f_3 e_t^y + e_t^P,$$

where the *f's* represent new constants. Indeed, there are six possible orderings that can explain the observed correlation in reduced-form errors.

In the general case, a causal ordering amounts to assuming that the endogenous variables enter the system in a triangular fashion, with the first equation containing one endogenous variable, the second two variables, the third three variables, and so on, giving a specific form to the *A* matrix. The reduced-form errors are written as a similar triangular sum of independent errors, or "innovations." Clavijo (1987), for example, applies a triangular ordering to his seven-equation model of the Colombian economy. However, Bernanke (1986) and Blanchard (1989), moving the VAR methodology closer still to structural estimation, have noted that the exclusion restrictions do not have to be so precisely distributed. Rather, the zeroes can be interspersed through the identifying matrix, as long as the number of unknowns is kept equal to the number of equations (and no linear dependencies are introduced).[8] Simple algebra allows a VAR to be given a structural interpretation, directly specifying the form of *A* and using reduced-form results to completely detail the model. Indeed, an identification scheme may place even more zeroes in the *A* matrix, with the nonzero coefficients estimated by a maximum-likelihood technique. Such a decomposition would not exactly replicate the correlation matrix of the residuals, with the extent of the shortfall providing a measure of the identification scheme's inadequacy.[9]

After experimenting with a variety of possible *A* matrices, we report

[8] In formal terms, the system must be just identified.

[9] Technically, the variance-covariance matrix can be written as a complicated product of the assumed structural parameters; in turn, those unknowns are estimated by a maximum-likelihood technique.

Table 5. *Impulse Response: A Traditional Ordering*

(Percent difference of level of each variable from baseline)

Variable	Years Ahead	Money	Interest Rate[a]	Income	Wages	Prices	Exchange Rate
Money	0	4.2	0.6	0.5	-0.2	-0.0	-2.6
	1	4.2	2.2	0.6	2.5	2.2	-1.7
	3	4.9	1.4	0.1	4.1	4.4	-2.5
	9	6.4	0.6	-0.7	7.1	7.4	0.9
Interest rate	0	0.0	3.4	0.0	0.0	0.0	1.0
	1	0.3	2.7	-0.4	0.2	0.4	2.8
	3	1.5	1.7	-0.8	1.1	1.6	6.7
	9	3.5	0.5	-1.2	2.4	4.4	10.7
Real GDP	0	0.0	-0.7	1.3	-0.5	-0.1	-1.7
	1	-0.7	-0.1	1.6	-1.4	0.1	-3.9
	3	-1.7	-0.6	1.6	-1.9	-1.7	-6.5
	9	-2.2	-0.1	1.6	-2.2	-2.4	-6.6
Wages	0	0.0	4.1	-0.5	0.2	5.2	2.6
	1	1.7	0.9	-0.5	-1.1	4.9	0.6
	3	1.7	1.2	-0.7	0.5	5.8	1.8
	9	2.9	0.3	-1.1	1.7	7.5	3.9
Prices	0	0.0	0.4	-0.0	3.8	0.5	0.2
	1	-0.3	1.9	-0.4	5.8	2.8	1.0
	3	0.4	1.0	-0.8	7.3	4.0	0.6
	9	1.5	0.4	-1.4	9.5	6.3	3.0
Exchange rate	0	0.0	0.0	0.0	0.0	0.0	5.1
	1	0.8	0.0	0.2	-1.3	0.6	7.4
	3	1.6	-0.4	0.8	-3.0	0.4	7.4
	9	0.9	-0.2	1.2	-4.1	-0.8	5.7

[a]Percentage difference from the baseline.

two alternative representations, each using 11 parameters to proxy for the 15 free parameters in the correlation matrix standing in for competing macroeconomic paradigms.

The Neo-Keynesian Structure

The first set of priors imposed on errors captures a traditional transmission mechanism. The money stock, set by policy, is only affected by its "own" shocks, so that any correlation among money and the other variables comes from the independent influence of money on those variables. A traditional money demand relationship characterizes the interest rate equation, while the output equation has the interpretation of an *IS* schedule. Prices are marked up over wages, which, in turn, are described by a Phillips curve. Lastly, the nominal exchange rate reflects a policy feedback rule. As detailed below, an equation in the ordering is subject to its own shocks and some fraction of the shocks to other equations in accordance with this set of theoretical priors. Omitting lagged endogenous variables and constant terms, our version of the neoclassical system can be summarized by an exogenous money stock:

$$\Delta M_t = e_t^M$$

the demand for money:

$$i_t = \alpha_{21} \Delta M_t + e_t^i + \alpha_{23} \Delta y_t + \alpha_{25} \Delta P_t$$

an *IS* schedule:

$$\Delta y_t = \alpha_{31} \Delta M_t + e_t^y + \alpha_{35} \Delta P_t$$

a Phillips curve:

$$\Delta W_t = \alpha_{43} \Delta y_t + e_t^W$$

a markup equation:

$$\Delta P_t = \alpha_{54} \Delta W_t + e_t^P$$

and, last, a feedback rule for the exchange rate:

$$\Delta E_t = \alpha_{61} \Delta M_t + \alpha_{62} i_t + \alpha_{63} \Delta y_t + \alpha_{65} \Delta P_t + e_t^E.$$

Using this ordering permits a full simulation of the model that exploits the temporal and contemporaneous relationships among the variables. Six such simulations are given in the panels of Table 5. Each panel reports the effect on the levels of all the variables of a 1 standard deviation shock

Table 6. *Variance Decompositions at Different Horizons: A Traditional Ordering*

(Percent explained by each variable)

Growth rate of	Years Ahead	SEE[a]	Money	Interest Rate[b]	Income	Wages	Prices	Exchange Rate
Money	0	4.2	100.0	0.0	0.0	0.0	0.0	0.0
	1	4.6	80.9	0.4	2.2	0.3	13.0	3.2
	3	4.9	74.5	3.3	4.2	1.4	11.8	4.8
	9	5.1	70.6	6.3	4.4	2.1	11.9	4.7
Interest rate	0	5.4	1.3	39.3	1.6	0.5	57.3	0.0
	1	6.7	11.9	40.6	1.0	8.0	38.4	0.0
	3	8.0	19.0	38.8	2.2	9.3	30.1	0.6
	9	9.0	22.2	37.0	2.2	11.0	26.3	1.3
Real GDP	0	1.5	10.3	0.0	79.7	0.1	9.9	0.0
	1	1.6	9.8	5.3	70.1	4.6	8.4	1.9
	3	1.8	12.0	8.1	57.6	6.8	7.9	7.7
	9	1.9	15.1	8.0	52.8	8.1	8.1	7.8
Wages	0	5.2	0.0	0.0	0.0	0.9	99.1	0.0
	1	6.2	12.9	0.4	0.1	14.2	71.5	0.9
	3	6.7	18.0	2.1	3.9	13.7	61.5	0.8
	9	7.1	19.1	4.8	3.8	14.2	56.9	1.2
Prices	0	3.8	0.2	0.0	1.6	97.9	0.2	0.0
	1	5.5	25.0	0.2	3.5	60.4	5.5	5.4
	3	6.0	23.9	1.3	4.1	53.2	8.4	9.1
	9	6.3	26.4	1.9	3.8	50.6	8.3	9.0
Exchange rate	0	6.6	15.6	2.5	6.5	0.1	15.1	60.2
	1	7.8	12.3	6.6	13.2	1.0	16.7	50.2
	3	8.7	10.6	14.8	17.1	1.2	14.7	41.6
	9	9.1	12.2	17.1	15.6	2.3	14.3	38.5

[a] Standard error of the equation.
[b] Level.

to a particular equation. In the top set, that translates to a 4.2 percent increase in M1 in the first year, which results in an increase in income and the other nominal domestic variables, as well as a decline in the exchange rate. In turn, those shocks feed through the economy over time.

Given a complete simulation of the model, the evidence on the neutrality of money is more mixed. The 6.4 percent increase in M1 over time produces higher interest rates and lower income. With the demand for real balances presumably lower, the price level increases by more than the nominal money stock. Wages lag slightly behind prices, so that the real wage falls. As explained in Blanchard (1990), this pro cyclical movement in wages is a common occurrence in developed countries, confounding the predictions of most sticky-wage models. The other simulations reveal that positive real or nominal shocks are not accommodated in the money stock. In the long run, the money stock is lower after independent shocks to income or inflation, while it is only slightly higher after a shock to wages.

The response of the system to a nominal exchange rate shock (a depreciation) also makes evident other nonneutralities. A devaluation initially increases prices-but reduces wages.[10] The combination of a lower real wage and increased exports could possibly explain the increase in output.. While the stimulative short-run consequences of a devaluation are frequently addressed in the literature, the more surprising result is that this nominal shock appears to have long-lived effects, as output continues to increase and the real wage decline persists.

An ordering also permits a decomposition of the forecast errors over any horizon into the parts attributable to specific structural errors. Such a decomposition is provided in Table 6 for the six dynamic variables. As the first column of the first panel indicates, the within-year forecast of money growth has a standard error of about 4Yz percent.. Quite reasonably, forecasts made further ahead have relatively larger standard errors.[11] With this ordering, most of that variability can be attributed to

10The reduction in the real wage may perhaps be explained by considering the relative labor intensiveness of the traded and nontraded sectors. If the latter is more labor intensive, as is usually thought, then the wage decline could be the outcome of a sectoral reallocation of factors toward the traded goods sector.

11 Here, it is important to remember the time-series properties of each variable. Forecasts of the level of the money stock compound each intervening year's variance of the forecast of the growth rate of the money stock. Thus, the standard error attached to a forecast of the level of the money stock expands as the forecast horizon lengthens, so that it is unbounded in the limit-the level of the money stock has a nonstationary distribution. Only the interest rate, which is estimated in levels, has a well-defined long-run limiting distribution.

money shocks (since about 70 percent of the variance is traced to its own shocks), not the influence of other shocks on money.

Significantly, the sizable variation in the policy-directed, short-term interest rate comes from its own shocks, as well as M1 shocks. This suggests, supporting the Calvo-Vegh thesis, that the interest rate on a liquid bond should be thought of as an independent instrument of policy, rather than the automatic outcome of the control of the nominal money stock.[12] With this in mind, the two instruments of monetary policy explain a large share of the variability in nominal magnitudes—over 28 percent of inflation variability and 24 percent and 29 percent of the uncertain part of wage inflation and the change in the exchange rate, respectively. Real activity is also similarly affected.

The estimated structural coefficients are interesting in their own right, because they speak to the substantial within-year movement among the key macroeconomic variables. Consider the coefficients of the A matrix that are significantly different from zero at the 90 percent level:

$$\Delta M_t = e_t^M$$

$$i_t = .74\,\Delta P_t + e_t^i$$

$$\Delta y_t = .11\,\Delta M_t - .05\,\Delta P_t + e_t^Y$$

$$\Delta W_t = e_t^W$$

$$\Delta P_t = e_t^P$$

$$\Delta E_t = -.54\,\Delta M_t + e_t^E.$$

Several features are worth noting. First, contemporaneous money and prices are significant in the output equation, indicating that output depends positively on real balances, thus according monetary shocks a role in the business cycle. Second, prices and wages do not appear to be affected by any contemporaneous shock (other than their own), suggesting a significant predetermined component in these variables. Last, only contemporaneous inflation appears as significant in the interest rate equation—neither income nor money shocks have a significant effect. The absence of the latter suggests that interest rates may be a "separate" instrument.

[12] In the case of Colombia the explanation for this "separability" may lie in the highly differentiated and active system of reserve requirements as well as a fairly complex system of directed credit.

A Real Business Cycle Structure

A growing literature asks that movements in real variables be interpreted as the outcome of real shocks. Such impulses then alter the rate at which households trade current for future consumption, leading to allocative reshuffling fully reflected in prices. In the end, the nominal money stock endogenously adjusts as the banking system accommodates a changed demand for a transactions media. One ordering consistent with the real business cycle approach would be a cash-in-advance constraint that explains the presence of money:

$$\Delta M_t = e^M_t + a_{13}\Delta y_t + a_{15}\Delta p_t + a_{16}\Delta E_t$$

a Fisher equation that links the nominal interest rate to the real interest rate, which in turn varies with output:

$$i_t = e^i_t + a_{21}\Delta y_t + a_{25}\Delta p_t$$

technology-determined output:

$$\Delta y_t = e^y_t$$

a real wage equation:

$$\Delta W_t = a_{43}\Delta y_t + e^W_t + a_{45}\Delta p_t$$

a markup equation to determine nominal prices:

$$\Delta p_t = a_{54}\Delta W_t + e^p_t$$

and the determinants of the real exchange rate:

$$\Delta E_t = a_{62} i_t + a_{63}\Delta y_t + a_{65}\Delta p_t + e^E_t.$$

This ordering allows a different and unique partitioning of the correlation among variables and, accordingly, results in different simulations and variance decompositions, which are presented in Tables 7 and 8. This new ranking accords to real shocks more important and long-lasting effects on the economy, with the income shock apparently embodying a permanent productivity shift. The shock to income persists and is also associated with an increase in the real wage.

Despite the radically different ordering, the lessons for monetary policy are similar. First, there is no evidence that real or nominal shocks are accommodated. In the long run, the money stock is lower after shocks to real income, the CPI, and the exchange rate, and only 1½ percent higher after a near 9 percent wage shock. Second, approximate domestic neutrality holds, as the increase in the CPI about matches the increase

Table 7. *Impulse Response: Real Business Cycle Ordering*
(Percent difference of the level of each variable from baseline)

Variable	Years Ahead	Money	Interest Rate*	Income	Wages	Prices	Exchange Rate
Money	0	4.6	0.0	0.0	0.0	0.0	0.0
	1	5.3	1.8	0.3	2.7	2.5	2.5
	3	6.5	1.1	0.2	3.4	5.3	1.6
	9	7.4	0.5	-0.5	6.0	7.5	3.7
Interest rate	0	-0.5	3.4	0.0	0.0	0.0	0.6
	1	-0.3	2.5	-0.4	0.1	0.1	2.0
	3	0.7	1.6	-1.0	1.1	1.1	6.0
	9	2.8	0.5	-1.3	2.2	3.9	10.0
Real GDP	0	1.7	-1.3	1.4	-0.6	-1.1	-2.6
	1	0.9	0.4	1.8	-0.2	-0.0	-3.7
	3	0.2	-0.3	1.7	-0.6	-1.0	-6.6
	9	-0.1	0.0	1.5	-0.1	-1.1	-6.1
Wages	0	1.6	4.1	0.0	0.4	5.1	1.1
	1	3.0	1.9	0.0	0.2	6.0	-0.9
	3	3.2	1.7	-0.4	2.5	7.4	-0.6
	9	4.9	0.6	-1.2	5.0	10.5	3.0
Prices	0	0.0	0.0	0.0	3.7	0.0	0.0
	1	-0.4	1.8	-0.3	5.9	2.3	0.9
	3	0.2	0.8	-0.7	7.2	3.4	0.5
	9	1.2	0.4	-1.3	9.3	5.6	2.7
Exchange rate	0	-4.0	0.0	0.0	0.0	0.0	5.5
	1	-3.7	-1.5	-0.0	-3.7	-1.6	5.6
	3	-3.9	-1.4	0.7	-6.1	-4.1	6.5
	9	-5.3	-0.6	1.7	-9.2	-7.0	2.8

* Percentage difference from the baseline.

Table 8. *Variance Decompositions at Different Horizons: Real Business Cycle Ordering*
(Percent explained by each variable)

Growth Rate	Years Ahead	SEE[a]	Money	Interest Rate[b]	Income	Wages	Prices	Exchange Rate
Money	0	6.6	49.1	0.5	6.9	0.0	5.7	37.8
	1	6.9	46.2	0.5	7.9	0.4	9.8	35.2
	3	7.0	45.9	1.6	8.0	0.9	9.4	34.1
	9	7.1	44.3	3.2	7.9	1.2	10.0	33.4
Interest rate	0	5.5	0.0	38.6	5.7	0.0	55.7	0.0
	1	7.1	6.3	36.8	3.9	6.3	42.0	4.8
	3	8.7	11.0	32.3	2.7	6.7	35.0	12.3
	9	9.9	12.0	29.7	2.1	7.7	32.7	15.8
Real GDP	0	1.4	0.0	0.0	100.0	0.0	0.0	0.0
	1	1.6	3.2	7.3	84.9	4.5	0.1	0.0
	3	1.8	2.8	10.4	68.0	6.4	3.6	9.0
	9	1.9	4.8	9.5	59.4	7.1	6.6	12.6
Wages	0	3.8	0.0	0.0	2.8	96.1	1.1	0.0
	1	6.3	18.0	0.0	1.5	45.6	0.5	34.5
	3	6.9	15.7	1.0	1.9	39.8	5.6	36.0
	9	7.3	16.2	1.3	1.9	36.9	7.2	36.5
Prices	0	5.2	0.0	0.0	4.6	0.0	95.4	0.0
	1	6.6	14.8	0.0	5.7	12.0	61.6	6.0
	3	7.5	20.8	1.1	5.4	10.7	49.8	12.2
	9	7.9	19.9	3.3	4.9	10.9	47.2	13.7
Exchange rate	0	6.2	0.0	1.0	18.0	0.0	3.0	78.0
	1	7.2	11.8	4.1	15.6	1.7	9.7	57.2
	3	8.2	10.4	14.7	20.0	1.7	8.0	45.2
	9	8.8	10.2	17.1	17.6	2.6	10.1	42.4

[a] Standard error of the equation.
[b] Level.

in the money stock after a purely monetary disturbance. Indeed, as the variance decomposition in Table 8 shows, monetary indicators still provide important information about the behavior of domestic prices. The short-term nominal interest rate and the stock of money account for about 23 percent and 27 percent of the CPI and exchange rate forecast errors, respectively (a similar percentage as in the previous ordering), suggesting that debate over the transmission mechanism should not cloud the central bank's ultimate responsibility for nominal magnitudes.

The response of the system to a nominal exchange rate depreciation has some common elements with its neo-Keynesian counterpart. As before, the exchange rate shock is associated with a long-lived real wage decline and an increase in output. Under both scenarios real balances increase, in tandem with the higher level of income and the slightly lower nominal interest rate. The implications for prices and the real exchange rate, however, are markedly different. In this ordering the nominal devaluation is accompanied by an even larger price decline, so that the real exchange rate appreciates.[13]

Considering only structural coefficients significantly different from zero at the 90 percent confidence level, three of the six equations become indistinguishable from their counterparts in the traditional ordering:

$$\Delta M_t = .34 M_t + e_t^M$$

$$i_t = .81 M_t + e_t^i$$

$$\Delta y_t = e_t^y$$

$$\Delta W_t = e_t^w$$

$$\Delta P_t = e_t^P$$

$$\Delta E_t = -1.63 \Delta y_t + e_t^E .$$

As before, the coefficient estimates indicate that prices and wages are largely predetermined (see also Table 9 in the Appendix) and only affected by their own shocks, while the interest rate equation is also unchanged. Output fluctuations now enter significantly in the exchange rate equation, apparently substituting for money, which had been significant in the traditional ordering. The distinctions between the two order-

[13] This outcome resembles a case considered by Lizondo and Montiel (1991), where the nominal devaluation is accompanied by an increase in government spending on nontraded goods. Their model predicts that the combined effect of the devaluation and fiscal adjustment produces a steady-state real appreciation and increased values of private wealth and expenditure.

ings mainly lie in the output and money equations. In the case of the former, the exogeneity restrictions result in a loss of information, as the correlations of output fluctuations with money and inflation shocks, apparent in the data, are lost in the estimated structural coeffficients. In the case of the latter, the estimates suggest that neither output nor exchange rate shocks affect money *directly,* while only price shocks turn out to be significant.[14]

These competing orderings each use 11 parameters to estimate the 15 distinct off-diagonal elements of the correlation matrix, but with quite distinct identification restrictions (the exception is the inflation equation). A reasonable way of assessing the adequacy of the competing models is to compare the results of a likelihood-ratio test for overidentification, which assays if the estimated coefficients can efficiently reproduce the actual correlation matrix of the reduced-form errors. A model's success is gauged by the extent to which important information is not lost by restricting the number of parameters, which suggests that the zeroes in the identification matrix were placed judiciously. This test statistic is distributed as a *l*, with degrees of freedom equal to the number of overidentifying restrictions-in our case, four. With our arbitrary real business cycle ordering, we confidently reject the null hypothesis that the estimated coefficients can reproduce the actual covariance matrix at any level of significance. For the traditional ordering the results are better, with less evident loss of information associated with the identifying restrictions-the null hypothesis cannot be rejected at the 90 percent level.[15]

III. Conclusion

Using annual data for Colombia over the last 30 years and a new battery of econometric techniques, we test opposing theories purporting to explain macroeconomic fluctuations: the neoclassical synthesis, which posits that in the presence of temporary price rigidity an unanticipated monetary expansion produces output gains that erode over time with increases in the price level; and an alternative explanation focusing on "real" technological or preference shocks as the sources of output changes. The estimates of both the temporal linkage (the VARs) and the

[14] Note, however, that in this ordering the nominal exchange rate does explain a significant share of the total variation in money (Table 8).

[15] The X^2-statistics for the real business cycle and traditional orderings are 19.344 and 5.655, respectively, with accompanying significance levels of 0.0007 and 0.23.

contemporaneous relationship (the estimates of the off-diagonal elements of the covariance matrix) present evidence that, in the case of Colombia, a neoclassical-Keynesian framework describes the dynamics of output better than an alternative that accords no role to monetary shocks.

Tests for overidentifying restrictions indicate that the results for the traditional ordering are better, with less evident loss of information associated with the identifying restrictions. This said, however, care must be taken not to overinterpret the test results, since they crucially depend on an arbitrary ordering. It is quite possible that an alternative representation of the real business cycle framework can explain a higher proportion of the covariance matrix than the ordering presented here.[16]

This relatively atheoretical approach to the macroeconomic time series highlights several empirical regularities for this small partially open economy.

First, the sizable variation in the policy-directed, short-term interest rate is due to its own shocks, as well as M1 shocks. This suggests, supporting the Calvo-Vegh thesis, that the interest rate should be thought of as an independent instrument of policy, rather than the automatic outcome of the control of the nominal money stock.

Second, a complete simulation of the model, irrespective of the ordering used, presents mixed evidence on the neutrality of money. An increase in M1 over time produces a small increase in interest rates and a slight decline in output. With the demand for real balances presumably lower, the price level increases by more than the nominal money stock. Wages lag slightly behind prices, so that the real wage falls. As explained in Blanchard (1990), this procyclical movement in wages is a common occurrence in developed countries. A change in the nominal exchange rate is also reflected in a change in the real exchange rate, similar to Mussa's findings in his examination of nominal and real exchange rates in developing countries (Mussa (1986)). Put another way, this reduced-form evidence suggests that disinflation efforts are not costless, since output falls in the short run as the result of a reduction in the rate of growth of the money stock.

Third, the behavior of the money stock does not lend support to models where money is an endogenous "passive adapter.". In a temporal sense, money is independent of lagged values of any variable but important in influencing the subsequent development of nominal variables. Variance

[16] For this number of parameters we did not find such an ordering.

decompositions show money to be largely determined by its own shocks, while other simulations reveal that positive real or nominal shocks are not accommodated in the money stock. In the long run, the money stock is lower after independent shocks to income or inflation, while it is only slightly higher after a shock to wages.

Last, our results highlight the important role institutional arrangements play in shaping the relationships among macroeconomic time series. The pervasiveness of long-term labor contracts is obviously instrumental in according monetary shocks a role in the determination of output fluctuations. The relative exogeneity of the money stock must be the by-product of the limited extent of capital mobility in the Colombian economy (see, for instance, Renhack and Mondino (1988)). Similarly, the complex and differentiated system of reserve requirements and directed credit to a large extent may account for the "separability" of interest rates and money stock. In some sense, we have relearned an old lesson that is familiar in the literature on the correlation between money and economic activity. Cagan (1988, p. 2) describes a particularly rich vein in that tradition: "A broad historical analysis goes beyond a narrow dependence on time series regressions. It draws on a wide-ranging examination of the institutional environment and economic events in a series of historical episodes."

This paper has attempted to efficiently characterize the comovements of an important set of macroeconomic variables so as to bring into clear relief such institutional detail and the key channels of monetary transmission.

APPENDIX

Sources and Estimation Results

This Appendix provides a listing of variables and their sources. Table 9 sets out the results of the estimations of the reduced-form model presented in Section I.

International Financial Statistics (IFS) was the source for money stock (Ml); prices (CPI) and (WPI); real GDP; export coffee price; and exchange rate (period average). Breaks in the *IFS* data on Ml were filled by applying the Ml growth rate reported by Banco de la Republica to the *IFS* level.

Banco de la Republica was the source for the average wage for manufacturing employees and minimum wage; and the Departamento de Planeacion Nacional was the source for the average yield on 90-day CDs from banks and finance corporations.

Table 9. *Vector Autoregressions, 1960–87*

Dependent Variable	Money	Interest Rate	Real GDP	Wages	Prices	Exchange Rate
Observations	28	28	28	28	28	28
R^2	0.36	0.69	0.40	0.64	0.50	0.53
$R\text{-}BAR^2$	0.17	0.60	0.23	0.54	0.36	0.39
SSR	488.65	861.04	56.32	403.37	771.12	1074.98
SEE	4.82	6.40	1.64	4.38	6.06	7.15
DW	1.98	2.38	2.04	1.82	2.07	2.00
Q	12.77	8.83	37.75	10.53	13.01	14.19
Money$_{t-1}$	0.14	0.38	0.06	0.58	0.55	0.54
	(0.22)	(0.29)	(0.07)	(0.20)	(0.27)	(0.32)
Interest rate$_{t-1}$	0.04	0.79	-0.12	0.15	0.09	0.38
	(0.19)	(0.25)	(0.06)	(0.17)	(0.24)	(0.28)
Real GDP$_{t-1}$	-0.34	0.45	0.18	-0.73	0.55	-0.96
	(0.65)	(0.86)	(0.22)	(0.59)	(0.81)	(0.96)
Wages$_{t-1}$	-0.11	0.48	-0.09	0.56	0.62	0.25
	(0.18)	(0.23)	(0.06)	(0.16)	(0.22)	(0.26)
Prices$_{t-1}$	0.19	-0.41	0.09	-0.32	-0.15	-0.97
	(0.22)	(0.29)	(0.08)	(0.20)	(0.28)	(0.33)
Exchange rate$_{t-1}$	0.16	0.00	0.04	-0.25	0.11	0.43
	(0.12)	(0.16)	(0.04)	(0.11)	(0.15)	(0.18)
Constant	15.50	-6.34	5.03	4.80	-9.35	3.94
	(6.05)	(8.03)	(2.05)	(5.49)	(7.60)	(8.97)

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