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ABSTRACT

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This paper documents changes in the cyclical behavior of nominal data series that appear after 1979:Q3 when the Federal Reserve implemented a policy to lower the inflation rate. Such changes were not apparent in real variables. A business cycle model with impulses to technology and a role for money is used to show how alternative money supply rules are expected to affect observed business cycle facts. In this model, changes in the money supply rules have almost no effect on the cyclical behavior of real variables, yet have a significant impact on the cyclical nature of nominal variables.

Keywords: Business Cycle Facts, Endogenous Monetary Policy, Real Business Cycles

JEL Classification: E32, E42, E50

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Introduction

One of the main ideas to come out of real business cycle theory is that a significant share of the variation in the real economy can be accounted for with a simple economic model of production and consumption that abstracts from money. The credibility of this finding is associated with the relative stability of the covariance structure of real aggregate data across time and countries, as documented by Backus and Kehoe (1992). The relative constancy of the business cycle facts guides model development.

Unfortunately, attempts to include money and inflation are problematic. When money and prices are added to the data series, the covariance structure becomes unstable and the search for a monetary structure becomes more complicated. Backus and Kehoe present evidence contrasting the stability of the covariance structure of real data series with the instability in the cyclical behavior of money and prices. They use annual data to compare the correlations measured across three periods, before World War I, the interwar period, and post World War II. Further evidence on the instability of the output-price correlations can be found in Cooley and Ohanian (1991), Pakko (1997), Smith (1992), and Wolf (1991). In this paper, we use postwar quarterly data to document the changes in the nominal data series that are apparent after October 1979 and to show how a change in the money supply rule may account for such instability. [1]

The first part of this article describes the business cycle facts. There is an important break in the covariance structure in 1979:Q3 when the Federal Reserve implemented a policy to lower the inflation rate. [2] We present Wald statistics suggesting that the changes in cyclical behavior are significant. There is some doubt about the validity of the distributional assumptions underlying the Wald tests. Therefore, we also use Monte Carlo methods to construct small-sample test statistics which provide strong evidence of a break in the cyclical behavior of money and prices about the time of the Fed's policy change.

The second part of the paper experiments with alternative money supply rules in a business cycle model with impulses to technology. In this model, the cyclical nature of the nominal variables can be highly sensitive to small changes in the decision rule governing the money supply. However, such changes have almost no impact on the cyclical behavior of the real variables. Finally, we present results which suggest that attempting to increase control over the money supply may account for the sort of changes we document.

The Facts

We begin by updating some of the business cycle facts presented in Kydland and Prescott (1990) and, more recently, in Cooley and Hansen (1995). The Hodrick-Prescott filter was used to define the business cycle components of the data series. The first column of statistics in Table 1 reports the percentage standard deviation of each variable and the other columns report the cross-correlations with real GDP. The statistics reported in Kydland and Prescott used data for a different sample than is used here. For GNP components and price data, their sample period begins in 1954:Q1 and ends in 1989:Q4. Their sample for the monetary data begins in 1959:Q1. We use a sample of data from 1959:Q1 through 1994:Q4. Instead of GNP, we follow current government practice and switch to the GDP data. Despite these differences in data and time periods, our reported correlation coefficients are, in most cases, virtually identical to those reported by Kydland and Prescott. The components of consumption and investment are highly procyclical. Consumption of nondurables and services is less variable than output, while expenditures on durables and all the components of investment are much more variable than output in percentage terms.

Like the real variables, the statistics reported for the price level and money supply measures in Table 2 also appear to have nearly the same variability and cross-correlation with real output as reported by Kydland and Prescott. Both the GDP deflator and the CPI move countercyclically. The monetary base varies procyclically and contemporaneously with output while M1 and M2 move procyclically and lead output by a quarter or two. Measures of velocity also move procyclically. Base velocity tends to move coincidentally while the velocity of M1 and M2 lag the cycle in real GDP.

Taken as a whole, the statistics show little change with the addition of five years to the sample. However, if we break the sample after 1979:Q3, we see a significant change in some of the facts. The correlations among the real variables are apparently unaffected, but the correlation between real output and the nominal variables is altered dramatically. We should note that one real variable, velocity, also appears to behave differently across the two periods. In general, we include velocity with the monetary variables because the demand for real balances may depend on the money supply rule.

Table 3 reports the results for the real variables when we treat 1979:Q3 as a breakpoint in the data. It was at the end of this quarter that the Federal Reserve announced a major change in operating procedures and a new commitment to reducing the inflation rate through controlling the money supply. Apparently, this policy change had almost no measurable effect on the cyclical behavior of hours worked or on the components of consumption and investment.

In contrast to the results for the real variables shown in Table 3, the business cycle facts for prices and money shown in Table 4 are different in the two periods. The variability of the price measures is similar across periods. However, the negative cross-correlations between the deflator and real GDP become much larger in absolute value for leads of three to five quarters. The absolute values of the contemporaneous and lagging correlations fall. The differences across periods for the CPI are similar to differences observed in the GDP deflator.

Substantial changes occur in the variability of the monetary aggregates around t rend. The narrow monetary aggregates, the monetary base and M1, are less variable before 1979:Q3 than afterward, while the broad monetary aggregate, M2, becomes less variable after 1979:Q3. All of the aggregates are less procyclical in the second period than in the first. The contemporaneous correlation of the monetary base with real GDP falls by about one-fourth, from 0.46 to 0.34. The contemporaneous correlations of M1 and M2 drop dramatically, from 0.71 to 0.18 and from 0.64 to -0.04, respectively.[3]

To test whether changes in the correlation coefficients are statistically significant, we construct a Wald test to compare the null hypothesis that the correlation coefficient in the latter period is equal to the correlation coefficient in the earlier period against the alternative that they are not equal.[4] If the two data series are treated as random samples drawn from a bivariate normal distribution, then the Wald statistic is distributed as a Chi-square with one degree of freedom. The 10 percent critical value is 2.71.

Table 5 reports the Chi-square statistics for the real variables. It includes the results of testing 77 cross-correlations between real GDP and other real variables across the two periods. Only in two cases (highlighted in Table 5) do the calculated statistics exceed the ten percent critical value. In contrast, the top panel of Table 6 reports the results of testing 55 cross-correlations calculated between real GDP and nominal variables. Here, 33 of the 55 are above the 10 percent critical value. For every nominal variable, at least part of the cross-correlation structure is significantly different after 1979:Q3. The bottom panel of Table 6 presents results for velocity. Here, 20 of 33 statistics exceed the ten percent critical value. Of course, we cannot be sure how much the actual data differ from the maintained assumptions of the Wald test. However, the main point is simply to emphasize the difference between the nominal and real cases.

We provided a check on the reliability of the Wald test by constructing simulated critical values from 1000 repetitions of the following experiment. Using actual data from the earlier period (not deviations from trend), we estimated a bivariate vector autoregression that includes real GDP and one of each of the other variables. In every case, we recovered estimates of autoregressive parameters and the covariance matrix. Then these estimates were used with a random number generator to create 1000 artificial series for each pair. Each series is 144 periods long. These series were then detrended, the sample split at period 83 (corresponding to 1979:Q3 in the U.S. sample), and the cross-correlations calculated for each subsample. For each artificial series, the Wald test was constructed to determine stability across the two periods. The 1000 test statistics were sorted by size, and the one-hundredth largest is reported in parentheses in Tables 5 and 6.

Use of the simulated critical value makes the two rejections for the real data no longer significant (see Table 5). In the case of the nominal variables and velocity shown in Table 6, the number of significant changes drops from 33 to 20 out of 55. For the velocity measures, we find that 12 of the 33 tests reject the null hypothesis. Even though there is a reduction in the number of rejections using the Monte Carlo method, a dramatic difference in the cyclical stability of real versus nominal variables remains.

A Model of Aggregate Fluctuations With Monetary Policy

The model used here—a modification of one developed by Kydland (1991) to examine the role of money in business cycles—is based on a neoclassical growth model with technology shocks. In each period, the consumer decides how to allocate time between work and leisure. Larger money balances increase the amount of time that can be allocated to these two activities. Money enters the economy as a government transfer. In Kydland, the money supply is treated as an exogenous univariate process. In this paper, the money supply function also depends on last period's output. This extension allows us to investigate the implications of a central bank's decision about whether to focus more sharply on nominal or real variables.

The Economy

The model economy is inhabited by many households that are all alike. Their available time, T, is spent in three basic activities: input in market production, leisure, and transaction-related activities such as trips to the bank, shopping, and so on. The role of money is to make the third activity less time consuming. By holding larger money balances, households have more time for work and/or leisure.

Assume that the time spent on transactions-related activities in period t is given by the expression

$$w_0 - w_1\left(\frac{m_t}{P_t c_t}\right)^{w_2},$$

where m_t is the nominal stock of money, P_t is the price of physical goods relative to that of money, and c_t is consumption expenditures. By restricting T_1 and T_2 to have the same sign and $T_2 < 1$, the amount of time saved increases as a function of real money holdings in relation to consumption expenditures, but at a decreasing rate. Leisure in period t is

$$\ell_t = T - n_t - w_0 + w_1\left(\frac{m_t}{P_t c_t}\right)^{w_2}, \quad (1)$$

where n_t is time spent in market production.

Each household maximizes

$$E\sum_{t=0}^{\infty}\beta^t u(c_t,\ell_t),$$

where $0 < \beta < 1$ is a discount factor. The functional form of the current-period utility function is

$$u(c_t,\ell_t)=\frac{1}{1-\gamma}\left[c_t^{\mu}\ell_t^{1-\mu}\right]^{1-\gamma}, \tag{2}$$

where $0 < \mu < 1$ and $\gamma > 0$ but different from one. This CES function, with unitary substitution elasticity between consumption and leisure, was chosen because it is consistent with postwar U.S. data in which long-run hours worked per person remain roughly constant despite the large increase in real hourly compensation.

The household's stock of capital, k, is governed by the law of motion,

$$k_{t+1}=(1-\delta)k_t+x_t, \tag{3}$$

where $0 < \delta < 1$, δ is the depreciation rate, and x_t is investment. The budget constraint for the typical individual is

$$c_t+x_t+\frac{m_{t+1}}{P_t}=w_t n_t+\frac{m_t+v_t}{P_t}, \tag{4}$$

where v_t is a nominal lump-sum transfer from the government.

Aggregate output, Y_t, is produced using labor and capital inputs:

$$Y_t=C_t+X_t=Z_t N_t^{\theta}K_t^{1-\theta}, \tag{5}$$

where Z_t is the technology level and X_t is the total of investment expenditures. The technology changes over time according to

$$Z_{t+1} = r \, Z_t + l_{t+1} \, , \tag{6}$$

where $0 < D < 1$. The innovations are assumed to be normally distributed with positive mean and with variance s^2_l.

A law of motion analogous to that for individual capital describes the aggregate quantity of capital. The distinction between individual and aggregate variables is represented here by lower and upper-case letters, respectively. This distinction plays a role when computing the equilibrium of a model with government policy in which the equilibrium is not simply the solution to a stand-in planner's problem.

Calibration

The model is calibrated using empirical estim ates of steady-state relations among the model’s variables and parameters. Most of the estimates come from long-run or average values. Measurements from panel data also are used. The parameter *2* in the production function equals the model’s steady-state labor share of output and is set equal to 0.65. This is in line with estimates obtained for the United States if approximately half of proprietors’ income is considered to be labor income. We use a quarterly depreciation rate of 0.025.

Turning to the household sector, the annual real interest rate is 4 percent, yielding a quarterly discount factor, *$*, of approximately 0.99. The risk-aversion parameter, *(*, is set equal to two, which means more curvature on the utility function than that corresponding to logarithmic utility. This value is consistent with the empirical findings of Neely, Roy, and Whiteman (1996).

We calibrate the money-time tradeoff so that the implied money demand function is consistent with the empirical evidence summarized by Lucas (1994) and Mulligan and Sali-Martin (1997). The money demand relationship in the model has a unitary elasticity of the scale variable (consumption). When we set T_2 (the curvature parameter in the money-time trade-off) equal to -1, the interest rate elasticity equals -0.5 .

With the steady state output and money stock normalized to unity, the steady-state price level is determined by choosing the annual income velocity of money to be 5.3—approximately equal to the average of M1 velocity between 1959 and 1994. Given the price level, we derive T_1 from the household's first order condition for the choice of money holding:

$$w_1 = \frac{r}{w_2 w} c^{w_2} \left(\frac{m}{P}\right)^{1-w_2}, \tag{7}$$

where the real wage rate, w, equals the steady state marginal product of labor, and r is the quarterly real interest rate. The implied value of T_1 is -0.0034. The magnitudes of T_1 and T_2 can be understood through a marginal evaluation around the average. If the real money stock is increased by 1 percent relative to its steady state, then a household's resulting weekly time saving is less than a minute.

Without loss of generality, we choose time units so that n + l = 1. In line with the panel-data estimates of Ghez and Becker (1975), we set n so that n/(n+ l) = 0.3. The remaining parameter µ, the share of consumption in the utility function, usually is determined from the condition MU_ℓ / MU_c = w and usually turns out to be close to n in magnitude. In this case, because of the dependence of time (and therefore l) on m/Pc, the corresponding condition can be written as

$$\frac{u_1}{u_2} = \frac{1}{w} + \frac{w_1 w_2}{c} \left(\frac{m}{Pc}\right)^{w_2}. \tag{8}$$

The implied value for μ is 0.33.

Monetary Policy

We modify the basic model to include a monetary policy function that changes the money supply growth rate in response to last period's level of output and the money stock. The alternatives we examine are all specific instances of the following general rule:

$$\boldsymbol{M}_{t+1} - \boldsymbol{M}_t = n_0 + n_1 \boldsymbol{Y}_{t-1} + n_2 \boldsymbol{M}_t + e_t, \tag{9}$$

where ν_1 is the proportional response to last period's output level, ν_2 is the response to the money stock, and e_t is the money supply shock in period t. If both ν_1 and ν_2 are 0, the money supply is a random walk. To judge the magnitude of ν_1, we note that the steady state value of Y is one. We do not estimate or calibrate the policy function in this paper. Recent work by Salemi (1995) suggests that, in future research, we may be able to calibrate the various policy rules that were in effect in the United States in the post-war period. In this paper we merely show that the quantitative implications of alternative policy rules on the nominal-to-nominal and nominal-to-real correlations can be large.

Dynamic Competitive Equilibrium

We compute the dynamic competitive equilibrium using the recursive method outlined in Kydland (1989) and Hansen and Prescott (1995). We take a quadratic approximation to the agent's utility function around the model's steady state, which is determined analytically. We eliminate consumption, leisure, the labor input, and investment with substitutions from the production function and the budget and time constraints. After these substitutions, utility becomes a function of state variables [individual state variables , $s_1 = (k_t, m_t)$, and aggregate state variables, $S_1 = (K_t, M_t)$ and $S_2 = (Z_t, V_t, Y_{t-1})$], the agent's decision variables, $d = (y_t, k_{t+1}, m_{t+1})$ and economy wide aggregates of the decision variables, $D = (Y_t, K_{t+1}, P_t)$. The aggregate price level rather than the aggregate money stock appears in D because prices must be determined so that the individual's choice of money holdings is consistent with the amount of money supplied by the central bank.

State variables at time t+1 are linear functions of state and decision variables at time t. In particular, lagged output shows up because of its presence in the central bank's reaction function. With a quadratic approximation to the utility function and linear transition equations for the state variables, the Bellman equation for the agent,

$$V_t(s_{1t}, S_{1t}, S_{2t}) = \underset{d_t}{\mathrm{Max}}\, E[U(s_{1t}, S_{1t}, S_{2t}, d_t, D_t) + b\, V_{t+1}(s_{1t}, S_{1t}, S_{2t})], \qquad (10)$$

has as its solution a quadratic form in the variables s_1, S_1, and S_2. Furthermore, the decision rules for the agent are linear in s_1, s_2, S, and D. Rules determining economy-wide variables are found by imposing consistency conditions. When the individual endogenous variables are identified with their aggregate counterparts, the individual decision variables must also be consistent with their aggregate counterparts.

An equilibrium is defined by a set of individual decision rules and an aggregate function. The individual decision rules solve the Bellman equation recursively and are consistent with the law of motion for technology and the policy rule. The decision rules determine a sequence of output, capital and money, $\{y_t, k_{t+1}, m_{t+1}\}$, for t = 1, ... The aggregate function produces a sequence of the aggregate variables $\{Y_t, K_{t+1}, P_t\}$ for t = 1, ... such that all markets clear, the individual decisions are consistent with the aggregate variables, and the price level is consistent with the sequence of individual money holdings and the monetary policy function.

Computational Experiments

Table 7 includes cyclical statistics calculated from the model economy with a fixed money stock; that is, with the ν_i's and the variance of ε set equal to 0. Like the U.S. economy, our model's consumption and investment are highly procyclical. In percentage terms, consumption is less variable, and investment is much more variable, than output. The price level is countercyclical. Velocity in the model moves procyclically.

With no money-stock variability, the variability of the price level in this model is below that observed in U.S. data. Still, with the benchmark of a constant money stock, variation in technology produces a cyclical standard deviation of the price level equal to 0.45, about half the standard deviation of the GDP deflator in the U.S. data (0.87 for the full sample [see Table 2]). When the benchmark assumptions are changed by increasing the variance of the money supply shock, the cyclical standard deviations of the price level and the money stock increase. When the standard deviation of the money supply shock is raised to 0.3 (0.6) percent per quarter, the standard deviation of the price level rises to 0.59 (0.89) percent. Raising the variance of the money supply shock tends to dampen the cyclical behavior of both money and prices. The contemporaneous correlation between output and the price level rises from -0.92 in the base case to -0.70 (-0.47) when the standard deviation of the money supply shock is raised to 0.3 (0.6) percent per quarter.

The sensitivity of the nominal-real covariance structure to variation in the policy parameters is reported in Figures 1 and 2. As in Table 7, the results of each experiment are averages of 100 independent model histories, each of the same length as the full U.S. sample. Each experiment uses different combinations of ν_1 (between 0.05 and -0.05) and ν_2 (between 0 and -0.1). The ranges were chosen because the cyclical properties of money and the price level were sensitive to choices for values within these ranges. For these computational experiments we have set the standard deviation of the money supply shock, ε_t, to 0.3 percent at a quarterly rate. Note that even when the variance of this error is set to 0, allowing money supply growth to be correlated with output induces realistic levels of variability in money and the price level.

We begin by looking at the behavior of the model economy when the cyclical response of policy to real output, ν_1, was varied between -0.05 and 0.05. Figure 1, panel A, shows the standard deviation of the price level, σ_p, and money stock, σ_m. Remember that the price level and the money stock are measured as log deviations from trend. When the standard deviation of the money shock was raised from zero to 0.3 percent in the base case, the standard deviation of the price level rose from 0.47 to 0.59. When money supply growth is made mildly procyclical (that is, when ν_1 is set equal to 0.015), the standard deviation of the price level falls to 0.41 percent. For the range of values examined, σ_m is relatively unaffected by the choice of ν_1.

Panel B shows how the cyclical behavior of the price level and the money stock is affected by changes in ν_1. The procyclical response of money growth that minimizes the variance of the price level also makes the price level acyclical. Increasing ν_1 above 0.015 induces procyclical movements in the price level. Lowering the parameter below 0.015 makes the price level countercyclical.

The cyclical behavior of the money stock does not appear to be highly sensitive to the choice of ν_1, but that appearance comes from looking only at the contemporaneous correlation between money and output, $\rho(y_t,m_t)$. Figure 1, panel C, shows the cross-correlations between output and the money stock at leads and lags of 3 quarters. When money supply growth is procyclical ($\nu_1 = 0.05$), the money stock leads the cycle, $\rho(y_t,m_{t-3})=0.28$. When money growth is countercyclical ($\nu_1 = -0.05$) the money stock lags the cycle, $\rho(y_t,m_{t+3})= 0.15$.

The sign of the policy response to output was an important factor in determining the cyclicality of the price level. When examining the effect of alternative responses to real output, we set ν_2 arbitrarily close to zero. Figure 2 shows what happens as the value of ν_2 is lowered from zero to -0.1. For these experiments, we assume that policy is procyclical (ν_1=0.05). This allows us to show how responding to the money stock can undo the effects of a procyclical policy on the price level. If we assume there is no response to output, the price level is highly countercyclical for all values of ν_2 that we examined.

When ν_2 is close to zero and ν_1 is set to 0.05, σ_p is 0.90 percent per quarter (see Figure 2, panel A). By lowering ν_2 to a value around -0.035, we can reduce the standard deviation of the price level to 0.17 percent. The standard deviation of the detrended money stock is relatively unaffected by changes in ν_2. As ν_2 is lowered from 0 to -0.1, σ_m declines very gradually from 0.46 to 0.44.

Panel B shows that the price level is highly procyclical when the money supply is close to a random walk and becomes countercyclical as ν_2 passes though -0.35. The money stock becomes slightly less countercyclical as ν_2 goes from 0 to -0.1. Panel C shows that the cross-correlations between output and money at leads and lags of 3 quarters display the same pattern; that is, the correlations rise as ν_2 is lowered to -0.1.

To summarize the main results in Figures 1 and 2, we find that changes in the money supply process have significant effects on both the variability of the price level and the size and sign of the correlation between the nominal variables and output. These dramatic changes in the covariance structure of the nominal series occur in a model in which the monetary rule has almost no impact on real variables. Of all the real variables, hours worked is the most affected by the alternative monetary regimes. Even so, the results are not shown here because the differences are not apparent at two significant digits. Changes in the monetary policy rule have large effects on the correlations among nominal variables and on the cross-correlation structure between nominal and real series, without having any noticeable impact on the real variables.

Conclusion

The behavior of money and prices over the business cycle defies simple classification in empirical regularities. We documented the relative instability of the behavior of nominal variables vis-à-vis the behavior of real variables. Looking at the stability of cross-correlations between real GDP and each of seven real variables—personal consumption expenditures, expenditures on nondurables and services, expenditures on consumer durables, private domestic investment, fixed investment, hours worked, and productivity—we found that only in two of 77 cases did the Π^2 statistic reject the null hypothesis of stability at the 10 percent critical level. When we constructed Monte Carlo estimates of the statistic's distribution, even those two rejections were overturned. The results for the nominal variables—GDP deflator, CPI, monetary base, M1 and M2—were much different. Here, we were able to reject stability in 33 of 55 cases using the 10 percent critical region of the asymptotic distribution. When we used the simulated critical values, the number of rejections dropped to 20.

In the second part of the paper, we explored the possibility that the instability in the cyclical behavior of the nominal data is caused by instability in the money supply function. We modified a real business cycle model with a labor-leisure trade-off by adding a time-saving role for money balances. We also included a monetary policy function that could react to both real output and the money stock. In a variety of experiments testing the sensitivity of the model to the policy function parameters, we found that the cross-correlations of nominal variables with real GDP are sensitive to the specification of the policy rule. Whether the price level is procyclical or countercyclical depends importantly on whether the money stock is allowed to react to real factors and to the amount of persistence that the authorities induce in money supply shocks. These findings are obtained in a model in which the specification of the monetary rule has almost no impact on the cyclical behavior of real variables.

Endnotes

[1] Bryan and Gavin (1994) show how the change in the money supply rule in the third quarter of 1979 might explain the change in the cross-correlation between inflation and monetary base growth that occurred about that time.

[2] Rolnick and Weber (1997) show that the covariance structure of money, output, and prices seems to depend on whether a country is on a fiat or commodity money standard. Within a fiat money regime, Friedman and Kuttner (1992) use results from vector autoregressions to argue that a deterioration in nominal-real relationships followed the Federal Reserve's policy change in 1979:Q3.

[3] Cooley and Hansen (1995) report business cycle facts in Table 7.1. Their statistics for the CPI and the GDP price index are similar to those we report in Table 4 for the period from 1959:Q1 to 1979:Q3. The facts they report about the monetary aggregates are an average of the experience in both periods.

[4] See Ostle (1963) pp. 225-227, for a detailed description of the test statistic used.

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Table I. Cyclical Behavior of U.S. Quarterly Data / Real Variables[a]

Variable x	Std. Dev.	Correlations with RGDP from 1959:Q1 to 1994:Q4										
		x(t-5)	x(t-4)	x(t-3)	x(t-2)	x(t-1)	x(t)	x(t+1)	x(t+2)	x(t+3)	x(t+4)	x(t+5)
GDP in 1987 Dollars (RGDP)	1.62	0.05	0.25	0.46	0.68	0.86	1.00	0.86	0.68	0.46	0.25	0.05
Consumption	1.23	0.27	0.45	0.62	0.77	0.87	0.88	0.73	0.54	0.33	0.10	-.09
Durables	5.00	0.34	0.48	0.59	0.71	0.78	0.80	0.61	0.40	0.18	-.04	-.22
Nondurables and Services	0.83	0.18	0.38	0.57	0.73	0.84	0.86	0.74	0.59	0.40	0.19	0.01
Private Domestic Investment	7.72	0.14	0.29	0.46	0.63	0.79	0.91	0.76	0.55	0.31	0.08	-.15
Fixed Investment	5.63	0.15	0.32	0.50	0.68	0.83	0.90	0.81	0.63	0.42	0.19	-.03
Hours Worked (Estab.)	1.54	-.19	-.01	0.19	0.42	0.67	0.88	0.92	0.86	0.73	0.56	0.37
Productivity (RGDP/Hrs Worked)	0.80	0.47	0.54	0.55	0.56	0.47	0.35	-.01	-.26	-.48	-.58	-.59

[a] The data series are measured as deviations from trend.

Table II. Cyclical Behavior of U.S. Quarterly Data / Nominal Variables and Velocity[a]

Variable x	Std. Dev.	Correlations with RGDP from 1959:Q1 to 1994:Q4										
		x(t-5)	x(t-4)	x(t-3)	x(t-2)	x(t-1)	x(t)	x(t+1)	x(t+2)	x(t+3)	x(t+4)	x(t+5)
GDP Deflator	0.87	-.57	-.65	-.71	-.72	-.67	-.58	-.46	-.33	-.18	-.04	0.10
CPIU	1.42	-.60	-.71	-.76	-.77	-.71	-.59	-.42	-.26	-.07	0.11	0.27
Monetary Base	0.88	0.11	0.20	0.26	0.32	0.37	0.38	0.34	0.29	0.22	0.14	0.09
M1	1.94	0.24	0.30	0.35	0.39	0.38	0.31	0.20	0.10	0.01	-.05	-.07
M2	1.38	0.40	0.51	0.59	0.62	0.58	0.45	0.26	0.08	-.09	-.25	-.37
Base Velocity	1.40	-.35	-.24	-.08	0.13	0.34	0.55	0.50	0.39	0.28	0.18	0.07
M1 Velocity	2.29	-.38	-.32	-.25	-.13	0.03	0.22	0.26	0.26	0.24	0.20	0.14
M2 Velocity	1.71	-.56	-.51	-.41	-.23	0.01	0.29	0.37	0.40	0.41	0.42	0.40

[a] The data series are measured as deviations from trend.

Table III. Cyclical Behavior of Real Variables in Subperiods[a]

Variable x	Std. Dev.	Correlations with RGDP from 1959:Q1 to 1979:Q3										
		x(t-5)	x(t-4)	x(t-3)	x(t-2)	x(t-1)	x(t)	x(t+1)	x(t+2)	x(t+3)	x(t+4)	x(t+5)
Real GDP	1.67	0.03	0.24	0.46	0.69	0.86	1.00	0.86	0.68	0.45	0.22	-.01
Consumption	1.26	0.19	0.40	0.59	0.78	0.87	0.89	0.74	0.54	0.30	0.02	-.21
Durables	5.18	0.29	0.46	0.58	0.72	0.80	0.83	0.67	0.45	0.20	-.07	-.28
Nondur. & Serv.	0.86	0.10	0.31	0.53	0.73	0.83	0.84	0.73	0.56	0.35	0.09	-.14
Pvt. Dom. Invest	7.78	0.14	0.29	0.46	0.64	0.78	0.91	0.76	0.57	0.34	0.11	-.15
Fixed Investment	5.87	0.13	0.31	0.50	0.70	0.83	0.89	0.79	0.62	0.41	0.17	-.07
Hours (Estab.)	1.58	-.23	-.06	0.16	0.39	0.63	0.85	0.92	0.86	0.74	0.56	0.34
Productivity	0.89	0.45	0.54	0.57	0.60	0.51	0.38	0.00	-.24	-.48	-.59	-.61
	Std. Dev.	Correlations with RGDP from 1979:Q4 to 1994:Q4										
		x(t-5)	x(t-4)	x(t-3)	x(t-2)	x(t-1)	x(t)	x(t+1)	x(t+2)	x(t+3)	x(t+4)	x(t+5)
Real GDP	1.56	0.07	0.26	0.45	0.64	0.87	1.00	0.87	0.67	0.47	0.30	0.14
Consumption	1.18	0.38	0.53	0.64	0.74	0.86	0.87	0.71	0.54	0.37	0.22	0.07
Durables	4.72	0.41	0.52	0.60	0.67	0.74	0.74	0.52	0.34	0.14	0.00	-.14
Nondur. & Serv.	0.80	0.31	0.49	0.61	0.71	0.85	0.88	0.77	0.62	0.48	0.34	0.21
Pvt. Dom. Invest	7.63	0.12	0.26	0.43	0.60	0.80	0.91	0.77	0.50	0.26	0.04	-.16
Fixed Investment	5.22	0.18	0.34	0.48	0.65	0.84	0.93	0.83	0.65	0.43	0.23	0.02
Hours (Estab.)	1.54	-.14	0.05	0.24	0.46	0.73	0.91	0.93	0.85	0.72	0.57	0.40
Productivity	0.66	0.52	0.53	0.51	0.46	0.39	0.29	-.06	-.33	-.51	-.58	-.59

Table IV. Cyclical Behavior of Nominal Variables and Velocity in Subperiods[a]

Variable x	Std. Dev.	Correlations with RGDP from 1959:Q1 to 1979:Q3										
		x(t-5)	x(t-4)	x(t-3)	x(t-2)	x(t-1)	x(t)	x(t+1)	x(t+2)	x(t+3)	x(t+4)	x(t+5)
GDP Deflator	0.78	-.41	-.52	-.66	-.74	-.72	-.65	-.55	-.42	-.23	-.04	0.18
CPIU	1.38	-.49	-.67	-.81	-.86	-.83	-.74	-.57	-.38	-.16	0.09	0.30
Monetary Base	0.69	-.21	-.12	0.00	0.15	0.32	0.46	0.54	0.58	0.53	0.44	0.35
M1	0.94	-.16	0.03	0.28	0.52	0.65	0.71	0.67	0.56	0.41	0.27	0.11
M2	1.63	0.45	0.61	0.73	0.78	0.76	0.64	0.45	0.20	-.04	-.28	-.46
Base Velocity	1.07	-.10	0.07	0.24	0.44	0.61	0.79	0.60	0.40	0.23	0.09	-.07
M1 Velocity	0.96	-.11	-.04	-.01	0.09	0.27	0.51	0.39	0.29	0.20	0.11	0.03
M2 Velocity	1.59	-.62	-.63	-.59	-.44	-.23	0.07	0.17	0.29	0.39	0.49	0.55
Variable x	Std. Dev.	Correlations with RGDP from 1979:Q4 to 1994:Q4										
		x(t-5)	x(t-4)	x(t-3)	x(t-2)	x(t-1)	x(t)	x(t+1)	x(t+2)	x(t+3)	x(t+4)	x(t+5)
GDP Deflator	0.97	-.78	-.84	-.81	-.72	-.63	-.50	-.36	-.24	-.13	-.04	.02
CPIU	1.43	-.78	-.78	-.71	-.64	-.55	-.38	-.21	-.08	0.04	0.14	0.22
Monetary Base	1.10	0.44	0.54	0.55	0.51	0.46	0.34	0.19	0.09	0.02	-.04	-.06
M1	2.82	0.51	0.51	0.47	0.42	0.33	0.18	0.02	-.09	-.15	-.18	-.16
M2	0.94	0.28	0.28	0.25	0.22	0.14	-.04	-.18	-.21	-.21	-.23	-.23
Base Velocity	1.82	-.62	-.55	-.38	-.15	0.13	0.40	0.45	0.40	0.33	0.26	0.17
M1 Velocity	3.40	-.61	-.55	-.42	-.26	-.06	0.17	0.28	0.31	0.31	0.27	0.20
M2 Velocity	1.90	-.48	-.35	-.17	0.05	0.33	0.60	0.63	0.54	0.44	0.34	0.24

Table V. Tests for Stability of Real Variables[a]

Variable x	Chi-square test for equality of correlations across sample periods (Break in 1979:Q3)										
	x(t-5)	x(t-4)	x(t-3)	x(t-2)	x(t-1)	x(t)	x(t+1)	x(t+2)	x(t+3)	x(t+4)	x(t+5)
Consumption	1.30 (6.12)	0.99 (5.77)	0.23 (5.59)	0.20 (6.52)	0.11 (8.36)	0.16 (9.05)	0.13 (6.04)	0.00 (5.31)	0.19 (5.40)	1.29 (6.16)	2.55 (6.80)
Durables	0.64 (5.91)	0.23 (5.96)	0.01 (6.67)	0.29 (7.64)	0.69 (8.37)	1.94 (7.44)	1.70 (5.01)	0.52 (4.41)	0.10 (4.78)	0.15 (5.10)	0.62 (5.51)
Nondurs.+ Srvcs.	1.63 (5.68)	1.44 (5.32)	0.40 (4.96)	0.07 (5.87)	0.13 (7.57)	0.56 (10.15)	0.31 (7.96)	0.29 (7.64)	0.87 (7.44)	2.40 (7.87)	4.10 (8.07)
Investment	0.01 (5.82)	0.03 (6.10)	0.06 (5.76)	0.14 (6.10)	0.11 (6.95)	0.01 (9.25)	0.01 (4.82)	0.32 (3.07)	0.24 (3.00)	0.15 (3.21)	0.01 (3.62)
Fixed Invest.	0.08 (6.86)	0.03 (6.68)	0.01 (7.47)	0.26 (7.71)	0.09 (9.45)	1.93 (12.71)	0.45 (7.95)	0.08 (5.47)	0.04 (4.65)	0.13 (4.56)	0.26 (5.32)
Hours Worked	0.23 (6.22)	0.39 (6.18)	0.23 (5.80)	0.24 (5.22)	1.07 (4.51)	2.98 (5.61)	0.51 (9.07)	0.07 (9.49)	0.10 (7.88)	0.00 (6.99)	0.18 (6.67)
Productivity	0.25 (9.69)	0.01 (8.40)	0.26 (6.80)	1.20 (5.31)	0.77 (4.87)	0.35 (4.85)	0.12 (3.76)	0.31 (4.21)	0.06 (5.77)	0.00 (6.63)	0.05 (7.07)

[a]Shading indicates that the Wald statistic rejects stability assuming the asymptotic 10% critical value, 2.71. Simulated 10% critical values are shown in parentheses.

Table VI. Tests for Stability of Nominal Variables[a]

Variable x	x(t-5)	x(t-4)	x(t-3)	x(t-2)	x(t-1)	x(t)	x(t+1)	x(t+2)	x(t+3)	x(t+4)	x(t+5)
	Chi-square test for equality of correlations across sample periods (Break in 1979:Q3)										
GDP Deflator	12.14 (9.59)	13.84 (10.33)	3.58 (10.76)	0.03 (11.10)	1.05 (11.94)	1.74 (11.87)	1.88 (10.39)	1.25 (9.04)	0.41 (8.06)	0.00 (7.64)	0.80 (7.42)
CPIU	8.61 (7.08)	1.87 (7.37)	1.84 (9.70)	8.97 (12.46)	10.65 (10.89)	9.76 (8.67)	6.28 (6.56)	3.47 (5.83)	1.31 (6.05)	0.08 (6.66)	0.26 (7.06)
Monetary Base	15.17 (7.39)	16.84 (6.72)	12.64 (6.38)	5.70 (7.03)	0.97 (7.24)	0.69 (8.02)	5.62 (7.83)	10.74 (8.65)	10.80 (9.28)	8.62 (9.56)	6.06 (10.43)
M1	16.64 (6.93)	9.39 (6.13)	1.69 (5.92)	0.51 (6.89)	6.04 (7.75)	17.08 (7.60)	21.06 (7.46)	17.21 (8.02)	11.68 (9.15)	6.65 (9.19)	2.40 (8.81)
M2	1.22 (8.75)	5.51 (8.76)	14.85 (10.17)	23.08 (11.60)	24.05 (10.12)	21.68 (7.84)	14.60 (6.74)	5.95 (6.86)	0.94 (7.85)	0.08 (9.50)	2.29 (10.48)

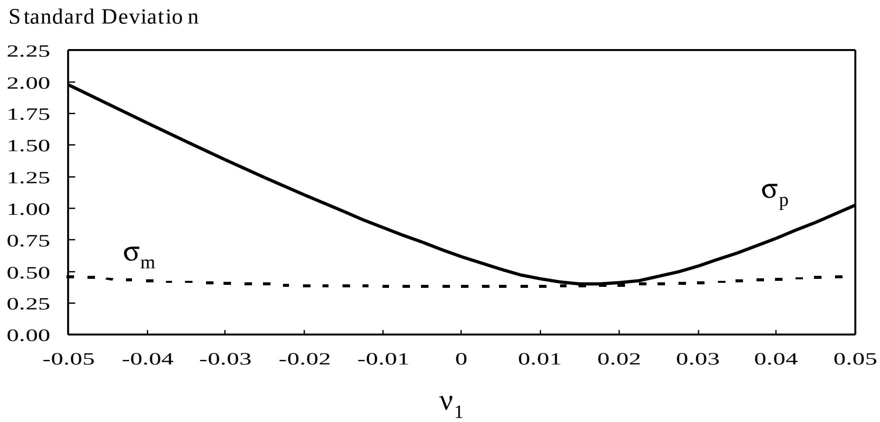
Tests for Stability of Velocity

Variable x	x(t-5)	x(t-4)	x(t-3)	x(t-2)	x(t-1)	x(t)	x(t+1)	x(t+2)	x(t+3)	x(t+4)	x(t+5)
	Chi-square test for equality of correlations across sample periods (Break in 1979:Q3)										
Base Velocity	12.57 (7.85)	15.21 (7.92)	13.61 (7.55)	12.91 (6.69)	11.07 (6.48)	13.79 (8.67)	1.46 (4.91)	0.00 (4.46)	0.43 (5.05)	1.09 (4.98)	1.87 (4.54)
M1 Velocity	11.46 (7.16)	10.57 (6.68)	6.17 (7.67)	4.40 (6.90)	3.81 (6.06)	5.03 (7.80)	0.47 (6.71)	0.02 (5.67)	0.50 (6.08)	0.96 (5.92)	1.00 (5.84)
M2 Velocity	1.35 (10.28)	4.27 (10.29)	8.25 (9.17)	9.10 (8.02)	10.96 (7.19)	12.95 (8.67)	10.94 (8.78)	3.23 (8.24)	0.10 (9.53)	1.01 (10.20)	4.48 (10.89)

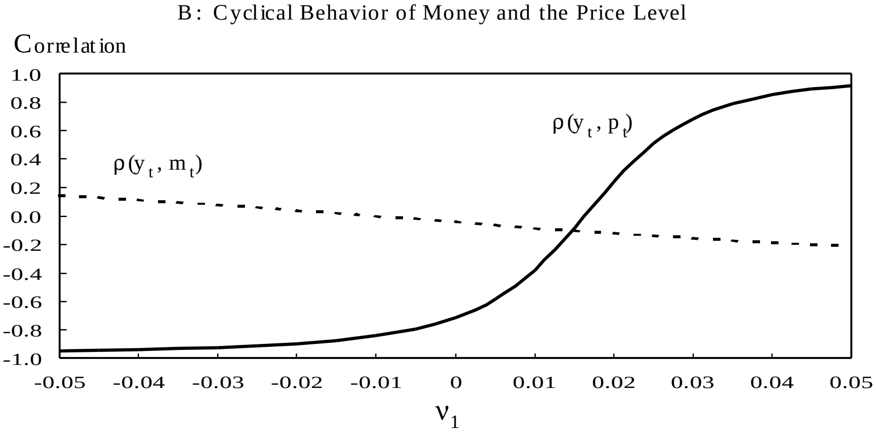
[a] Shading indicates that the Wald statistic rejects stability assuming the asymptotic 10% critical value, 2.71. Simulated 10% critical values are shown in parentheses; Light shading indicates that stability is not rejected using the simulated critical values.

Figure 1: Alternative Responses to Real Output[a]

A: Standard Deviation of the Price Level and the Money Stock

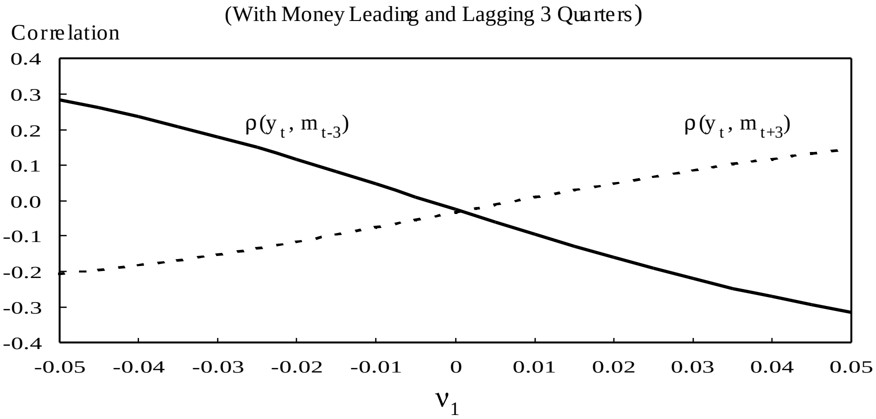


B: Cyclical Behavior of Money and the Price Level



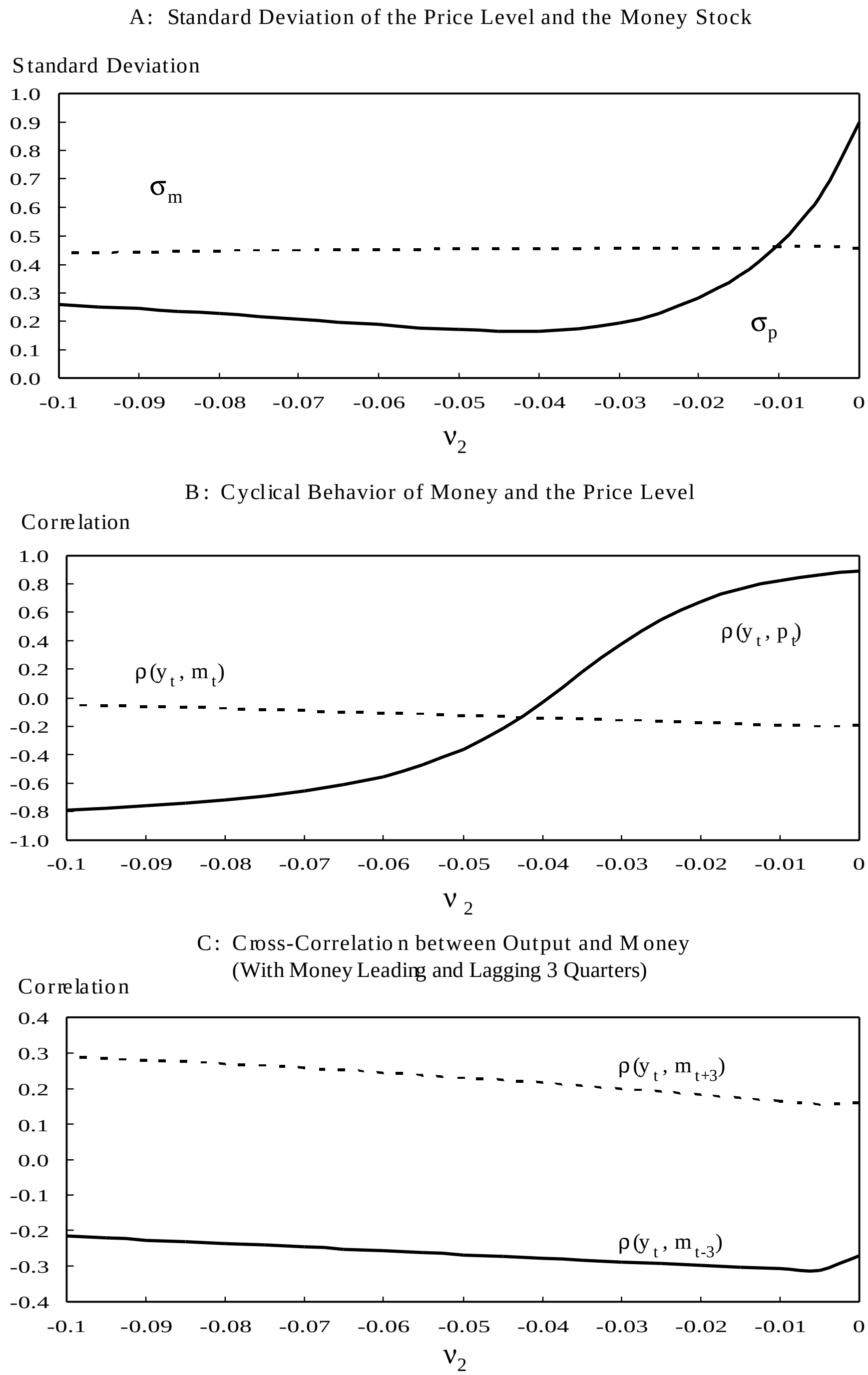
C: Cross-Correlation between Output and Money

(With Money Leading and Lagging 3 Quarters)



[a] ν_2 was set equal to 0 and σ_ε was set equal to 0.3 percent per quarter.

Figure 2: Alternative Responses to Money Stock[a]



[a] ν_1 was held constant at 0.05 and σ_ε was set to 0.3 percent per quarter.