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A DIFFERENT KIND OF MONEY ILLUSION:  
THE CASE OF LONG AND VARIABLE LAGS

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## I. Introduction

One of the stylized facts in the macroeconomics literature is the long and variable lag between the "money cause" and the "price effect."<sup>1</sup> The monetary transmission mechanism that underlies this relationship is poorly understood and is still a main bone of contention among macroeconomists. Important policy implications follow from one's belief about the nature of the linkage between money and the price level. If monetary policy affects prices only after a long lag, then monetary policy may have large effects on the real economy.<sup>2</sup>

The purpose of this paper is twofold. First, it is to show that the observed correlations between inflation and current and past money growth may be long even when the structural lags in the monetary transmission mechanism are not, as in the case of an economy with flexible prices.<sup>3</sup> This point should be obvious to those familiar with the literature on real business cycles or the rational expectations critique of econometric policy analysis. Yet, we note that many economists, both in research and in policy arenas,

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<sup>1</sup> See Friedman (1961) for an influential discussion of this issue. Purvis (1990) describes conventional wisdom about the lag from money to prices and the implications for policy. Rosenbaum (1985) presents a survey of the postwar literature.

<sup>2</sup> This issue is also important for the central bank's choice of policy target. The belief in a long lag has induced many economists to advocate intermediate targets for monetary policy. This pervasive view is illustrated in an April 25, 1991, *Wall Street Journal* article by Federal Reserve Bank of Richmond economist Robert Hetzel, who writes, "The obvious guide (to measure the impact of Fed actions on inflation) is the general price level. The long lag between monetary policy actions and changes in the price level, however, makes the price level an unsatisfactory guide."

<sup>3</sup> Tucker (1966) shows that a Keynesian model with short lags in the monetary transmission mechanism can generate data in which the lags from monetary growth to inflation appear to be long and variable. Tobin (1970) makes a similar comment on Friedman (1961) and his monetary research at the National Bureau of Economic Research. Lucas (1976) and Sargent (1976) show how rational expectations contribute to this identification problem.

continue to operate as if the implications of these models are not practically relevant. Our second purpose is to show why we think they are. We use a simple rational expectations model with flexible prices to explain why the lag between inflation and money growth appeared to be long before 1980 and why it has since disappeared.

In general, the covariance structure relating prices and money growth will be a function of the structural relationships in the economy, including the money supply function. Any change in the money supply function can cause a change in the observed covariance structure. Consider a simple model in which monetary changes feed immediately into the price level and the Federal Reserve adds persistence to monetary growth. To be explicit, let the logarithm of the price level be determined by the following:

$$p_t = \text{constant} + m_t + \epsilon_t, \quad (1)$$

where  $m$  is the log of the money supply and  $\epsilon_t$  is white noise. The money supply is given by

$$m_t = m_{t-1} + u_t; \quad u_t = \rho u_{t-1} + e_t. \quad (2)$$

Growth in the money supply is an autoregressive process;  $e_t$  is assumed to be white noise. The cross-correlations between inflation and past money growth will be proportional to the term  $\rho^i/(1-\rho^2)$ , where  $i$  is the number of periods that money growth is lagged. In this simple example, there is no lag in the monetary transmission mechanism, but there can be a long lag in the cross-correlation function relating inflation and monetary growth. All that is required to induce the appearance of a long lag between money growth and inflation is strong persistence in money growth. The cross-correlation declines with a smaller  $\rho$  and as the lag becomes longer. If the monetary

authority changes its operating procedures so that the persistence in money growth is reduced, the lags from money growth to inflation will also appear to be shorter.

An important shift in monetary policy occurred in October 1979, accompanied by a reduction in the autocorrelation in monetary base growth (see table 2 for an estimate of  $\rho$ ). The estimated value of  $\rho$  was 0.49 from February 1960 to September 1979; it fell to 0.28 from October 1979 to June 1991. Although the value of  $\rho$  shifted in a way that would reduce the cross-correlations between monetary growth and inflation, the estimated value (0.49) is not large enough to match the cross-correlations we see in pre-1980 U.S. data. Furthermore, this simple bivariate model does not identify the cause of the monetary persistence.

To investigate the sources of the observed lag, we use a slightly more complex model involving output as well as prices and money. The incomplete information model of Lucas (1973) is used to show that models with very short lags in the monetary transmission mechanism can easily generate the long lags in the cross-correlation function (relating inflation and money growth) that were present in U.S. data prior to 1980. The model is also useful for showing how the change in emphasis on monetary targeting in October 1979 could have made the apparently long lag from money growth to inflation virtually disappear in the 1980s.

## II. The Monetary Misperceptions Model

The Lucas model of monetary misperceptions may be useful for understanding monetary phenomena even if it does not explain the business cycle. As we show below, even when the Lucas model explains little of the

variance in output, it still predicts that the data will display the illusion of a long lag from money to prices if the monetary authority conditions money supply growth on real output.

Money has real effects in the incomplete information model because firms do not have enough information to separate the price effects of local real shocks from those originating in aggregate money shocks. As a result, agents respond to all local price changes as if they were due in part to real factors and in part to monetary factors. In this model, the structural lag from money to prices is only as long as the time it takes for people to learn about monetary policy.

The simple Lucas economy consists of isolated competitive markets in which firms must make production decisions before they know what monetary policy will be. Output supplied in the  $j^{\text{th}}$  sector is given by

$$y_{t,j}^s = \alpha_j + \beta (p_{t,j} - E_j p_t) + \rho y_{t-1,j}. \quad (3)$$

Output in each sector is equal to some natural level ( $\alpha_j/(1-\rho)$ ) plus a positive proportion of the perceived relative price change. The production process includes some unspecified source of persistence, represented by the first-order autocorrelation coefficient,  $\rho$ . Factors that cause persistence in output will affect the observed money-to-prices lag. It is possible that persistence in output is due to the structure of the money supply mechanism, but there are many nonmonetary reasons for persistence in real economies; examples include the time to build capital, the presence of inventories, the inability to transfer capital from one sector to another, the costs of training new workers, etc. This persistence was not part of the original Lucas (1972) specification, but it is one of the necessary ingredients for generating the apparent long lag from money to prices.

Output supply is affected by unanticipated changes in the money supply that cause a deviation between actual and perceived relative prices. Agents form rational expectations of the relative price,  $p_{tj} - E_j p_t$ , based on information available in sector  $j$ . This includes full information about the economy up to  $t-1$  and the current local price,  $p_{tj}$ .<sup>4</sup> For simplicity, both  $\beta$  and  $\rho$  are assumed to be the same across sectors.

Demand for output in sector  $j$  is given by

$$y_{tj}^d = \lambda_j + m_t - p_{tj} + \epsilon_{tj}. \quad (4)$$

The demand for sector output is equal to  $\lambda_j$ , the log of the share of money used in the sector, plus the logarithm of real money balances,  $m_t - p_{tj}$ , plus a local shock,  $\epsilon_{tj}$ , that is assumed to be drawn from a stationary distribution with mean zero and variance  $\sigma^2$ . Monetary velocity is constant in this model, as in a simple cash-in-advance specification.

Monetary policy determines the behavior of the money stock up to a control error that is assumed to be random, drawn from a distribution with mean zero and variance  $\sigma_u^2$ . The money supply is assumed to be governed by the following rule:

$$m_t = \mu + m_{t-1} + by_{t-1} + u_t. \quad (5)$$

The money stock is equal to the money stock last period plus some constant growth component,  $\mu$ , plus some function of output and a control error,  $u_t$ . This simple specification captures some important features of the real world.

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<sup>4</sup> See McCallum (1989) or Blanchard and Fischer (1989) for an introductory discussion of the Lucas model. The notation and specification used here are similar to those used by Ahmed (1987).

The log level of the money stock is not a stationary process; whether the growth rate is stationary depends on how the monetary authority responds to economic data. For nonzero values of  $b$ , the monetary authority conditions money growth on the level of output.<sup>5</sup> This is also an important ingredient of our model; if  $b = 0$ , then the policy is a constant money growth rule with noise, and the observed covariance structure between money and prices reflects the short structural lag in the money supply mechanism.

Aggregating over sectors, we get reduced-form solutions for inflation and the logarithm of aggregate output:<sup>6</sup>

$$\Delta p_t = \Delta m_{t-1} + \frac{1}{1 + \beta - \beta\theta} \Delta u_t + (b - \rho) \Delta y_{t-1}, \quad (6)$$

$$\text{where } \theta = \frac{1}{J} \sum_{j=1}^J \theta_j, \text{ and } \theta_j = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_j^2}.$$

$$y_t = \frac{\alpha}{1 - \rho L} + \frac{\phi}{1 - \rho L} u_t, \quad (7)$$

$$\text{where } \phi = \frac{\beta}{1 + \beta} \left( 1 - \frac{\theta}{1 + \beta - \beta\theta} \right).$$

The money supply rule (5) is the reduced form for the (log) money supply.

The covariance function relating current inflation to current and past money growth is given as  $\gamma_{pm}(k)$ , where  $k$  is the number of periods separating inflation and money growth. For aggregate inflation, the covariance function is

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<sup>5</sup> This may be thought of as a monetary response to the deviation of output from a constant trend without affecting our results.

<sup>6</sup> To simplify this aggregation, we assume that all of the sector shocks were drawn from the same distribution and that aggregate output is defined as the product, rather than the sum, of sector outputs. See Lucas (1972) for a more rigorous microeconomic derivation of this model.

$$\gamma_{pm}(0) = \left\{ \frac{1}{1 + \beta - \beta\theta} + \left[ 1 - \frac{1}{1 + \beta - \beta\theta} + (b-\rho)\phi \right] b\phi + \left[ \frac{b\phi^2(1+b-\rho)\rho^2}{1-\rho^2} \right] \right\} \sigma_u^2, \quad (8)$$

$$\gamma_{pm}(1) = \left\{ \left[ 1 - \frac{1}{1 + \beta - \beta\theta} + (b-\rho)\phi \right] + \frac{\rho b\phi^2(1+b-\rho)}{1-\rho^2} \right\} \sigma_u^2, \quad (9)$$

$$\gamma_{pm}(k) = \left\{ \rho^{k-1}\phi(1+b-\rho) + \frac{b\phi^2(1+b-\rho)\rho^k}{1-\rho^2} \right\} \sigma_u^2, \quad \text{for } k > 1. \quad (10)$$

Expressions for the variance of inflation and money growth are

$$\text{var}(\Delta p_t) = \left\{ \left( \frac{1}{1 + \beta - \beta\theta} \right)^2 + \left[ 1 - \frac{1}{1 + \beta - \beta\theta} + (b-\rho)\phi \right]^2 + \left[ \frac{(\rho\phi(1+b-\rho))^2}{1-\rho^2} \right] \right\} \sigma_u^2, \quad (11)$$

$$\text{var}(\Delta m_t) = \left[ 1 + \frac{b^2\phi^2}{1-\rho^2} \right] \sigma_u^2. \quad (12)$$

The observed cross-correlation between inflation in the aggregate price index and money growth will depend on the parameters  $\rho$ ,  $b$ ,  $\beta$ ,  $\theta$  and  $\sigma_u$ . Figure 1 shows the expected cross-correlation functions relating inflation to lagged money growth for a wide variety of parameter values. The baseline case (shown as the top line in each panel) has parameters  $\rho=.99$ ,  $b=.15$ ,  $\beta=1.5$ , and  $\theta=.09$ . In each panel of figure 1, one of the parameters is varied while the others are held at baseline values. The standard deviation of the monetary shock,  $\sigma_u$ , was set at .005 in all cases. The range of values of  $\rho$ ,  $b$ , and  $\theta$  were chosen based on empirical analysis that is reported below. The base value for the supply parameter,  $\beta$ , was arbitrarily set equal to 1.5.

The panel in the upper left-hand corner of figure 1 shows the cross-correlation function when the value of  $\rho$  is varied between .95 and .99 (we

examine two measures of output in the next section; both appear to have values of  $\rho$  that fall in this range).

The effects of varying  $b$ , the monetary policy parameter, are shown in the upper right-hand panel. The monetary policy parameter ranges from 0.05 to 0.15.<sup>7</sup> As we show below, the estimated value of  $b$  was about 0.1 for the two decades before 1980 and apparently zero during the 1980s. This model predicts that the cross-correlations should have become considerably smaller after October 1979, when the Federal Reserve apparently became more concerned about monetary targeting.<sup>8</sup>

The panel in the lower left-hand corner of figure 1 shows the cross-correlation functions for different values of the price elasticity of supply,  $\beta$ . The correlations are larger if output supplied is more sensitive to the relative price.

The lower right-hand panel shows the change in cross-correlations as  $\theta$  increases. For this parameterization of the model, there is little change in the covariance structure as  $\theta$  falls from 0.36 to zero.

### III. Empirical Evidence

The cross-covariance functions, equations (8) to (10), pertain to aggregate price inflation in a model where the only source of disturbance is

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<sup>7</sup> Figure 1 shows values of  $b$  from 0.05 to 0.25. As  $b$  goes from zero to  $-.03$ , the covariance function is slightly negative; at  $b = -0.04$ , the cross-correlation function again turns positive.

<sup>8</sup> We say apparently because a major change in operating procedures accompanied the announcement of a disinflation policy on October 6, 1979. Our model does not include the details about monetary institutions and money demand that are needed to explain why the inflation rate was stabilized after 1979, but the monetary growth rate apparently was not. See Poole (1988) for an excellent discussion of this issue.

an aggregate nominal shock. This results in a very high contemporaneous correlation (not shown in figure 1) that would be substantially reduced if aggregate real shocks were added to the model. Although more realism could be introduced by adding other sources of disturbance to the system, doing so is not necessary to make our main point that changing the money supply rule can have a dramatic effect on the observed cross-covariance structure relating money and prices. From sometime in the mid-1950s until the late 1970s, the Federal Reserve followed a policy that resulted in an uneven acceleration of the inflation rate. This persistence in the inflation rate might result if the Federal Reserve was using our money supply rule, equation (5), with  $b > 0$  and  $\rho$  near unity.

In October 1979, the Federal Reserve announced a commitment to reduce inflation and implemented a new operating procedure to enhance the credibility of the announcement. The result in the 1980s was lower inflation, which appears to have been random around a stable 4-1/2-percent growth trend. In our model such an outcome would result if  $\mu$ , the drift in the money growth rate, were equal to 4-1/2 percent per year and  $b$  were set equal to zero. The pattern of cross-correlations relating inflation and money growth that was observed in the pre-1980 data would disappear if the Federal Reserve adopted such a rule.

We use data from the Consumer Price Index (CPI), the Producer Price Index (PPI), and the monetary base to examine the covariance structure before and after October 1979. We also examine the corresponding output measures (personal consumption expenditures for the CPI and industrial output for the PPI) to obtain information about the approximate size of the parameters in the Lucas model.

In the real world there is no reason to expect the local shocks to sum to zero in each period (as was assumed in our model). Table 1 shows our estimates of  $\rho$  and  $\sigma$  for personal consumption expenditures and industrial output. These are taken directly from the equation used to estimate the augmented Dickey-Fuller test for the presence of a unit root (a time trend is included in the estimated equation). Although the estimate of  $\rho$  is often very close to unity, we can reject the hypothesis that the output series contains a unit root in all but one case.

Table 1 also shows our estimates of  $\rho$  and  $\sigma$  for the monetary base. Again, with a time trend included, we can reject the hypothesis that the series contains a unit root for the early subperiod, but the estimate is very close to unity. The noise in the monetary base is small relative to the noise in output (at most, the standard deviation of the innovation to the monetary base is only half the standard deviation of the innovation to output); these estimates suggest that  $\theta$  is probably less than 0.2.

Table 2 presents the results of estimating equation (5) directly from the data. Before October 1979, both lagged measures of output were positively and significantly related to growth in the monetary base. After October 1979, the average relation was not significantly different from zero.

In figure 2 we show the cross-correlations between monthly measures of inflation and monetary base growth. The correlations are presented for two measures of inflation (the CPI and the PPI) and two sample periods (January 1959 to September 1979 and October 1979 to June 1991). The cross-correlations are larger in the early sample and near zero after 1979. In both cases, the cross-correlations fell dramatically after the Federal Reserve changed from a policy that conditioned money growth on real output and that resulted in an

accelerating inflation rate to a policy that appears to be targeting inflation at a moderate 4 to 5 percent level (which would correspond to a constant 4 to 5 percent money growth rule in our model).

#### IV. Conclusion

Although we cannot prove that the observation of long lags in the money supply mechanism is an illusion, we can easily show that a long lag may be observed in the cross-correlations even if there is only a very short lag in the monetary transmission mechanism. We present a model in which the monetary transmission mechanism has a very short lag, but which can generate data that display a very long lag from money to prices.

We also show that the experience of the last three decades is consistent with this simple Lucas model of monetary misperceptions. The model predicts that if money supply growth is systematically related to lagged real output growth, as it was prior to the 1980s, then the lag from money to prices will appear to be long. Further, the model predicts that if the Federal Reserve announced and achieved a policy to stabilize the inflation rate, as it did in the 1980s, the long lag would disappear. In viewing the whole period, some might conclude that the lag was both long and variable.

As we noted above, the Lucas model of monetary misperceptions may be useful for understanding monetary phenomena even if it does not explain the business cycle. Modifying this model to account for real sources of business cycle fluctuations would not change our central result. The model would still predict the illusion of a long lag from money to prices as long as the monetary authority conditioned money supply growth on real output.

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Table 1. Persistence and Noise in Output and Money

<u>Variable</u>	<u>1961-91</u>		<u>1961-79</u>		<u>1979-91</u>	
	<u><math>\sigma</math></u>	<u><math>\rho</math></u>	<u><math>\sigma</math></u>	<u><math>\rho</math></u>	<u><math>\sigma</math></u>	<u><math>\rho</math></u>
Industrial Production	0.77	0.98*	0.79	0.97*	0.73	0.94*
Personal Consumption Expenditures	0.57	0.97*	0.52	0.96	0.63	0.89*
Monetary Base	0.28	0.98*	0.23	0.99*	0.34	0.91

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\* Indicates that, with a 5 percent critical region, we can reject the hypothesis that this variable contains a unit root.

Note: The standard deviations are in percent at a monthly rate.

Source: Authors' calculations.

Table 2. The Monetary Response to Output

$$\Delta m_t = \text{constant} + by_{t-1} + u_t$$

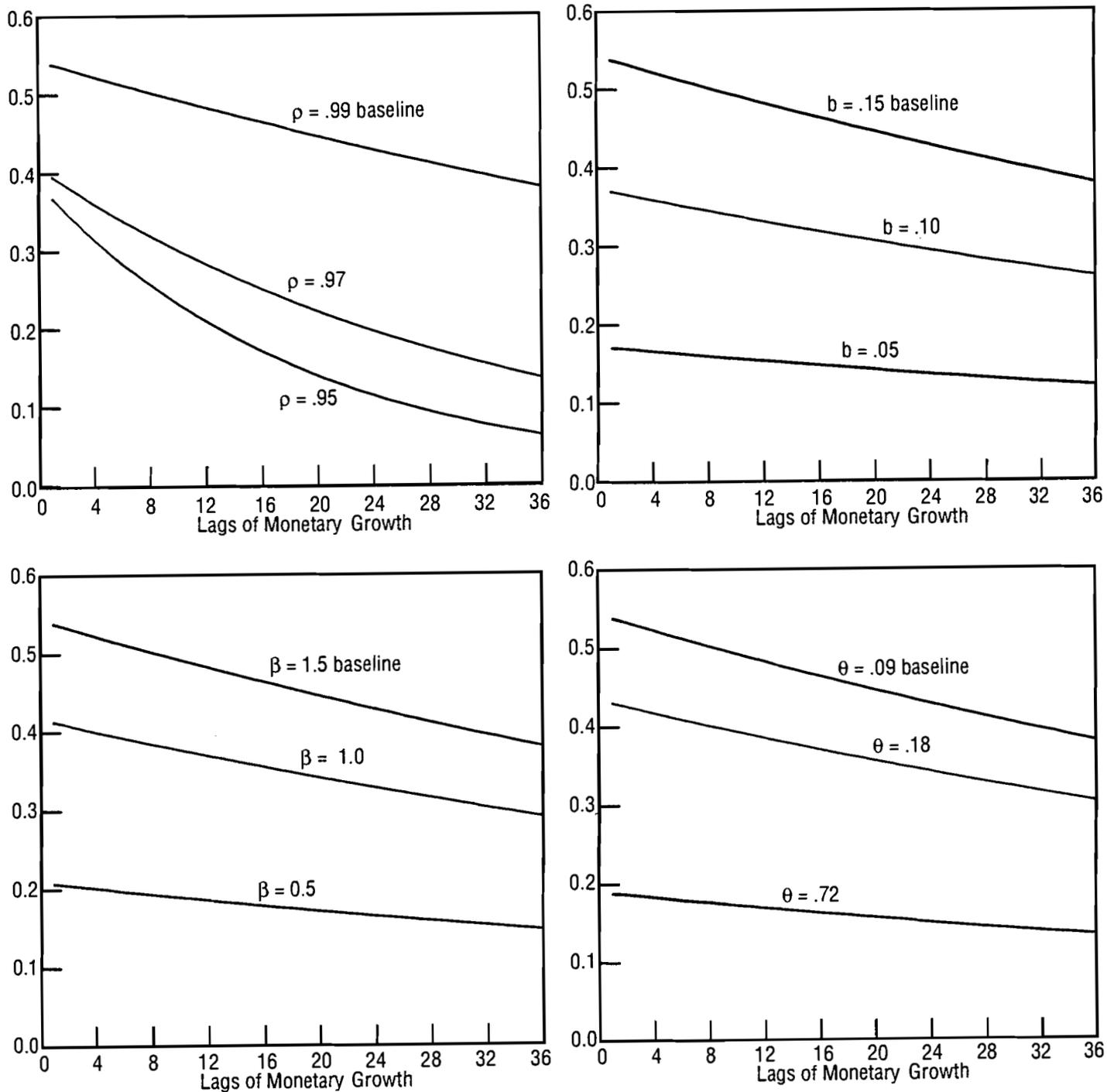
$$u_t = \rho u_{t-1} + \epsilon_t$$

<u>Log(output), y</u>	<u>January 1961 to September 1979</u>			
	<u>constant</u>	<u><math>\hat{b}</math></u>	<u>S.E.E.</u>	<u><math>\hat{\rho}</math></u>
--	0.055 (13.9)	--	3.17	0.49 (8.76)
Industrial Production	0.105 (20.9)	0.091 (10.9)	2.79	0.16 (2.47)
Personal Consumption Expenditures	-0.691 (-9.81)	0.102 (10.6)	2.80	0.17 (2.66)
	<u>October 1979 to June 1991</u>			
	<u>constant</u>	<u><math>\hat{b}</math></u>	<u>S.E.E.</u>	<u><math>\hat{\rho}</math></u>
--	0.073 (15.4)	--	4.03	0.28 (3.46)
Industrial Production	0.071 (13.1)	-0.027 (-0.59)	4.04	0.28 (3.42)
Personal Consumption Expenditures	0.023 (0.07)	0.006 (0.15)	4.05	0.28 (3.45)

Note: The standard errors of the equations (S.E.E.) are shown in percent at an annual rate.

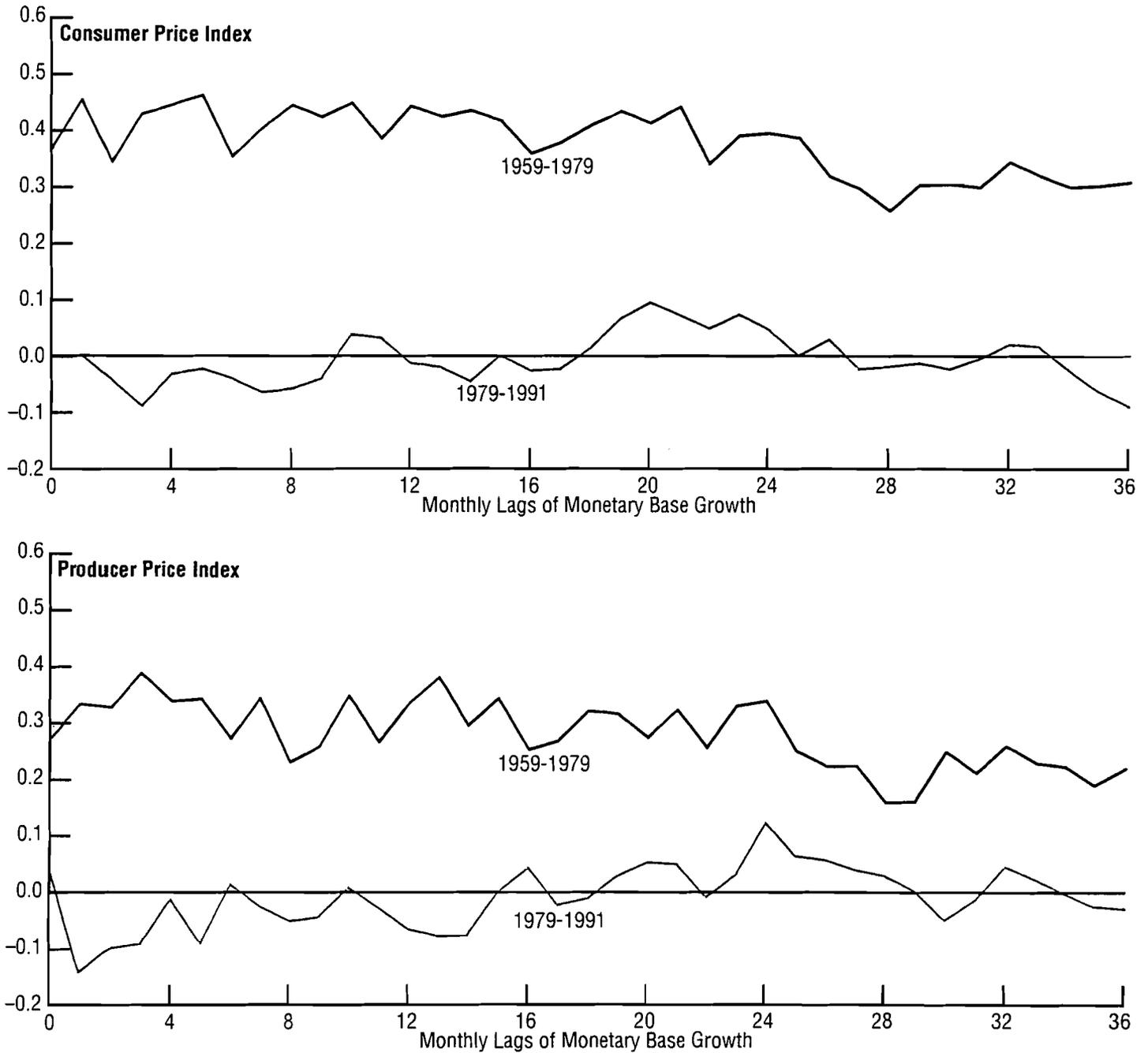
Source: Authors' calculations.

**Figure 1 Expected Cross-Correlations Under Alternative Parameterizations  
(Inflation and Monetary Growth)**



SOURCE: Authors' calculations.

**Figure 2 Historical Cross-Correlations  
(Inflation and Monetary Growth)**



SOURCE: Authors' calculations based on data from U.S. Department of Labor, Bureau of Labor Statistics.