Tests of Monetary Neutrality on Farm Output

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According to the monetary neutrality hypothesis, only the unanticipated money supply growth has impacts on real economic variables, and the anticipated money supply growth has no real impacts. The monetary neutrality hypothesis is tested on real farm output. The test procedure involves joint estimation of farm output and the money growth equation. The empirical results show that the anticipated money supply growth does have significant effects on farm output and, thus, do not support the monetary neutrality hypothesis.

Key words: monetary neutrality hypothesis, joint estimation, agricultural sector.

According to the "Monetary Neutrality Hypothesis" or "Natural Rate Hypothesis" (NRH) in the macroeconomic literature, the anticipated component of money supply growth does not affect real economic variables; only the random, unanticipated component affects real variables (Lucas 1972, 1973; Barro 1976). Building on microfoundations, Lucas and Barro developed theoretical models supporting the NRH. The framework used in these studies for the development of NRH was a simple environment with flexible prices. In the real world, however, prices (both input and output) are not freely flexible because of labor contracts, sales contracts, price support policies, etc. Thus, considerable controversy over the NRH has ensued since it was proposed in the early 1970s (see Gauger 1988). Subsequent theoretical studies of NRH incorporated nominal price rigidities and showed justifications for the nonneutrality of the anticipated money supply growth. For example, Fischer developed a model with multiperiod wage contracts and nominal wage rigidity to show the nonneutral impacts of the anticipated money supply growth on real economic activity. Phelps and Taylor obtained similar results using a model with nominal output price rigidity. Gauger (1984) specifically demonstrated that the anticipated money supply growth will have a positive (negative) effect on real economic activity if output price is relatively more (less) flexible than input prices.

Empirical tests of the monetary neutrality hypothesis also produced mixed results. For example, Barro (1977, 1978) and Barro and Rush, using aggregate data, obtained results in support of the NRH. On the other hand, Mishkin found that the anticipated money supply growth does affect real economic variables; moreover, contrary to the implications of the NRH, the unanticipated money supply growth does not have a larger impact on real variables than the anticipated money supply growth. These empirical studies used aggregate data, even though the theoretical underpinnings of the notion of neutrality as implied by the models of Lucas and Barro build upon the supply and demand functions of an individual market or sector. These theoretical models signify that the anticipated money supply growth has no real effect, not only at the aggregate level but also at the disaggregate or sectoral level if prices are flexible. However, money neutrality at the aggregate level does not necessarily imply that the hypothesis holds at the disaggregate level if input and/or output prices are rigid in some sectors. For example, Blinder and Mankiw point out that aggregate level evaluation of monetary shocks can present a false picture

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of the disaggregate level impacts. Thus, testing of the NRH is needed at the sectoral level also.

The focus of this study is to test the NRH in the U.S. agricultural sector. Specifically, the objective of this study is to examine the neutrality of the anticipated and unanticipated money supply growth on real farm output. The agricultural sector traditionally has been characterized as a flexible price sector. This characterization of the agricultural sector dates back to Cairnes' pioneering study more than a century ago. Cairnes asserted that prices of primary products with inelastic supply and demand would respond rapidly to an increase in money supply. Along the same line, Bordo found that agricultural prices are more responsive to monetary shocks than industrial prices because agricultural products are traded in well-developed auction markets.

Bessler, in an important study, tested the hypothesis that agricultural prices are more responsive to money supply changes than industrial prices for the Brazilian economy. He used a vector autoregression to test the hypothesis, and his conclusions were that agricultural prices do not adjust faster than industrial prices to money supply shock. Gardner, and Grennes and Lapp found that relative prices are not affected by shocks in macroeconomic variables. On the other hand, Chambers concluded that, by using data for the United States, relative prices increase in the short run in response to an unanticipated increase in money supply. Devadoss and Meyers, and Orden found that farm prices respond faster than manufactured prices to a money supply shock. In a recent study Robertson and Orden concluded that the dynamic relationships between money and prices for New Zealand are consistent with long-run neutrality. Saunders and Bailey found a unidirectional causal flow from the monetary base to the U.S. nominal gross farm product. Their results also indicated a strong positive impact of money supply on agricultural prices and a small negative impact on real farm output. In a recent article Saunders found a unidirectional causal flow from the monetary base to retail-level agricultural prices.[1]

Articles that specifically examined the NRH in agricultural markets include studies by Enders and Falk, and Azzam and Pagoulatos. Enders and Falk provided empirical evidence supporting the NRH in the pork industry. However, when Azzam and Pagoulatos tested the NRH in pork and beef markets by better accounting for the appropriate biological relationships and by including additional lags of anticipated and unanticipated money supply growth, they found only scant support for the NRH. Rausser et al. noted that because of the price support programs of agricultural policies there is an asymmetry in the effects of monetary policy on the farm sector. They also provided a detailed summary of forward and backward linkages between the agricultural sector and the rest of the economy.

In the next section a theoretical model to illustrate the NRH is developed based on the premise that agricultural prices are flexible. The approach used in the model is the localized markets framework of the rational expectations model developed by Barro (1976) and Hercowitz. This is followed by the description of the estimation procedure used in testing the NRH. Specifically, the NRH is tested by using a joint estimation procedure, which estimates the money forecasting equation and farm output equations as a simultaneous system. Next, the empirical results are presented. The results indicate that both the anticipated and unanticipated money supply growths have significant impacts. Finally, a brief summary and policy implications are provided.

Theoretical Model

The primary object of this section is to develop a theoretical model to illustrate the NRH; i.e., that only the unperceived money supply growth has effects on relative prices and, thus, on real farm output. The first step is to specify supply and demand functions for output and government policy rule and to solve for the farm output prices. The second step is, by using the method of undetermined coefficients, to obtain reduced-form equations for farm output prices, economy-wide aggregate prices, and relative prices. The final step is to derive a reduced-form solution for farm output.

The theoretical model employed in this study is a simple extension of the model developed by Hercowitz, which is a modification of the partial information-localized market framework of the rational expectations model originally developed by Barro (1976). According

[1] Saunders and Bailey, and Saunders examined the effect of total money supply without decomposing the effects of anticipated and unanticipated money supply growth.

to this framework, the anticipated money supply growth is recognized as economy-wide shocks and results in price changes in all sectors. But the unanticipated money supply growth is misinterpreted as market-specific shocks because market participants with imperfect information cannot distinguish between aggregate and market-specific shocks. As a result, only the unanticipated money supply growth has an effect on the real economic variables.

Let the output supply function of the agricultural sector, denoted by *z*, be given as:

$$(1) \quad y_t^s(z) = \alpha^s(z)[P_t(z) - EP_t] + \epsilon_t^s(z), \qquad \alpha^s(z) > 0,$$

where $y_t^s(z)$ = log of farm output supplied, $P_t(z)$ = log of farm output price, P_t = log of economy-wide aggregate price, and t = time index. The operator E denotes the mathematical expectation taken conditional on all the available information. The information set includes lagged values of all relevant variables, some economy-wide shared knowledge about current variables related to money supply, and also current information on $P_t(z)$ which is known only to the participants in the market z. $P_t(z) - EP_t$ is the perceived relative price by the producers in the agricultural market. A positive response of supply to the perceived relative prices is measured by the elasticity $\alpha^s(z)$. The stochastic disturbance term, $\epsilon_t^s(z)$, is assumed to be generated by identically and temporally independent supply shocks, such as drought, pest attacks, etc.

The specification of the farm output demand function is given by:

$$(2) \quad y_t^d(z) = -\alpha^d(z)[P_t(z) - EP_t] + b^d(z)[M_t - EP_t] + \epsilon_t^d(z), \quad \alpha^d(z) > 0,\ b^d(z) > 0,$$

where $y_t^d(z)$ = log of farm output demanded and M_t = log of aggregate money stock. Price speculation by demanders implies a negative effect of $[P_t(z) - EP_t]$ on quantity demanded, as measured by the elasticity $-\alpha^d(z)$. The demand function also includes the term $M_t - EP_t$ to reflect the effect of aggregate shocks on quantity demanded. The stochastic disturbance term, $\epsilon_t^d(z)$, is assumed to be generated by identically and temporally independent demand shocks. The excess demand shifter, $\epsilon_t(z) \equiv \epsilon_t^d(z) - \epsilon_t^s(z)$, is assumed to be serially uncorrelated and normally distributed with mean zero and variance σ_ϵ^2.

The analysis proceeds with the assumption that agents have full information about the relevant aggregate variables with a one-period lag, current economy-wide variables related to monetary policy, and also market-specific current information that is limited to an observation of the current price, $P_t(z)$. Market participants do not know the current prices in other markets. The key elements of this model are individuals possessing incomplete current information and making supply and demand decisions by responding to relative prices as they are locally perceived. Because of the lack of information, participants are not able to differentiate between the aggregate and market-specific shocks. As a result, individuals believe that any unanticipated aggregate shock that causes changes in relative prices is a market-specific shock and, in turn, respond by changing their demand and supply behavior to these shocks, which leads to real effects of unperceived aggregate shocks.

To complete the model, it is necessary to specify the growth rate of money supply, which encompasses systematic and random components. That is,

$$(3) \quad M_t - M_{t-1} \equiv \Delta M_t \equiv m_t = m_t^e + m_t^u,$$

where m_t^e and m_t^u are anticipated and unanticipated growth rates of money supply at time t, respectively. Thus, m_t^e is the expected money supply growth based on all available information. The random component, m_t^u, is taken to be generated by a temporally independent white noise process with mean zero and variance σ_u^2.

The price in this market is determined by equating supply (1) and demand (2). The solution for price $P_t(z)$, after substituting for M_t from equation (3), can be written as:[2]

$$(4) \quad P_t(z) = \{1 - 1/[\alpha^s(z) + \alpha^d(z)]\}EP_t + \{1/[\alpha^s(z) + \alpha^d(z)]\} \cdot [M_{t-1} + m_t^e + m_t^u + \epsilon_t(z)].$$

Equation (4) is readily interpreted: $P_t(z)$ is determined by a set of "demand-pull" variables that include the money supply and the excess demand shifter, and a "cost-push" term, EP_t. Since participants know the prices of their commodities but not the prices in other markets, they form expectations about the economy-wide aggregate price based on $P_t(z)$ and

[2] To simplify the mathematical derivations, $b^d(z)$ in equation (2) is set equal to one.

other available information. The key element of the rational expectations approach is that the EP_t in equation (4) is not determined by an ad hoc expectations mechanism from outside the model but is based on all available information in the economy and knowledge implied by the structure of the model.

Now we proceed to solve the model for prices and output as a function of exogenous variables. First, the solution for prices in terms of exogenous variables is obtained by using the method of undetermined coefficients. Then, the price solutions are substituted into either the supply or demand function to obtain an expression for output. By utilizing the model's log linearity, it is reasonable to conjecture a reduced-form solution for the aggregate price as:

$$(5)\qquad P_t = \Pi_1 M_{t-1} + \Pi_2 m_t^e + \Pi_3 m_t^u,$$

where Πs are unknown parameters. The aggregate price is determined by the current money supply, which consists of M_{t-1}, m_t^e, and m_t^u [refer to equation (3)]. By realizing that M_{t-1} and m_t^e are fully perceived at time t, whereas the posterior expectation of m_t^u is conditional on market-specific information, the expected aggregate price can be written as:

$$(6)\qquad EP_t = \Pi_1 M_{t-1} + \Pi_2 m_t^e + \Pi_3 E m_t^u.$$

The key to the formation of the aggregate price expectations is the computation of Em_t^u conditional on the market-specific information, $P_t(z)$. The conditional expectations of m_t^u are calculated, in effect, by linearly projecting m_t^u on $P_t(z)$. That is,

$$(7)\qquad Em_t^u \mid P_t(z) = [\sigma_u^2/(\sigma_u^2 + \sigma_\epsilon^2)][m_t^u + \epsilon_t(z)].$$

Substituting (7) into (6), we find that

$$(8)\qquad EP_t = \Pi_1 M_{t-1} + \Pi_2 m_t^e + \Pi_3[\sigma_u^2/(\sigma_u^2 + \sigma_\epsilon^2)] \cdot [m_t^u + \epsilon_t(z)].$$

The expected aggregate price from (8) is substituted into market-specific price in (4) to obtain

$$(9)\qquad P_t(z) = [1 - \lambda(z)] \cdot \{\Pi_1 M_{t-1} + \Pi_2 m_t^e + \Pi_3[\sigma_u^2/(\sigma_u^2 + \sigma_\epsilon^2)][m_t^u + \epsilon_t(z)]\} + \lambda(z)[M_{t-1} + m_t^e + m_t^u + \epsilon_t(z)],$$

where $\lambda(z) = 1/[\alpha^s(z) + \alpha^d(z)]$. Summing market prices $[P_t(z)]$ across all markets and taking average yields, the aggregate price level[3]

$$(10)\qquad P_t = (1 - \lambda)\{\Pi_1 M_{t-1} + \Pi_2 m_t^e + \Pi_3[\sigma_u^2/(\sigma_u^2 + \sigma_\epsilon^2)]m_t^u\} + \lambda(M_{t-1} + m_t^e + m_t^u).$$

The average of $\lambda(z)$ is denoted by λ. Observe that equation (10) is identical to (5); thus, the three Π coefficients can be determined by matching the corresponding terms in the two equations. The resulting solution is

$$(11)\qquad \Pi_1 = 1,\ \Pi_2 = 1, \text{ and } \Pi_3 = (\sigma_u^2 + \sigma_\epsilon^2)/[\sigma_u^2 + (1/\lambda)\sigma_\epsilon^2].$$

These coefficients are substituted into (9) to obtain the market price, $P_t(z)$, and into (5) or (10) to obtain the aggregate price, P_t. The resulting expressions are

$$(12)\qquad P_t(z) = M_{t-1} + m_t^e + \frac{\sigma_u^2 + [\lambda(z)/\lambda]\sigma_\epsilon^2}{\sigma_u^2 + (1/\lambda)\sigma_\epsilon^2}[m_t^u + \epsilon_t(z)],$$

$$(13)\qquad P_t = M_{t-1} + m_t^e + \frac{\sigma_u^2 + \sigma_\epsilon^2}{\sigma_u^2 + (1/\lambda)\sigma_\epsilon^2} m_t^u.$$

The relative price, the difference between the market price and the economy-wide aggregate price, is determined by subtracting (13) from (12) as:

$$(14)\qquad P_t(z) - P_t = \frac{[(\lambda(z) - \lambda)/\lambda]\sigma_\epsilon^2}{\sigma_u^2 + (1/\lambda)\sigma_\epsilon^2} m_t^u + \frac{\sigma_u^2 + (\lambda(z)/\lambda)\sigma_\epsilon^2}{\sigma_u^2 + (1/\lambda)\sigma_\epsilon^2}\epsilon_t(z).$$

The important results for relative prices in (14) can be readily interpreted: the systematic part of monetary policy, m_t^e, has no effect on relative prices. The ineffectiveness of the systematic component of the monetary policy is because m_t^e is contained in the information set; therefore, agents take into account this information in forming the expectations. As a result, the anticipated money supply growth is captured in price expectations [in both $P_t(z)$ and P_t]; thus, relative prices are not affected by the systematic component of monetary policy. Stated differently, relative prices are neutral with respect to the systematic component of monetary policy. On the other hand, the unsystematic part of monetary policy, m_t^u, has an impact on relative prices. This is because the random component of money supply growth is not contained in the agents' information set and, thus, is not captured in the

[3] Note that the average of $\epsilon_t(z)$ over all markets is zero.

price expectations. As a result, the unanticipated money supply growth affects relative prices.

The next step is to derive an expression for output. To do that, it is useful to assess the difference between $P_t(z)$ and EP_t. First, we obtain EP_t by substituting (11) into (8):

$$(15) \quad EP_t = M_{t-1} + m_t^e + \frac{\sigma_u^2}{\sigma_u^2 + (1/\lambda)\sigma_\epsilon^2} \cdot [m_t^u + \epsilon_t(z)].$$

Subtracting (15) from (12), we get

$$(16) \quad P_t(z) - EP_t = \frac{[\lambda(z)/\lambda]\sigma_\epsilon^2}{\sigma_u^2 + (1/\lambda)\sigma_\epsilon^2} [m_t^u + \epsilon_t(z)].$$

By substituting (16) into the supply function or (15) and (16) into the demand function and rearranging terms, the reduced-form equation for output can be written as:

$$(17) \quad y_t(z) = \frac{1}{\sigma_u^2 + (1/\lambda)\sigma_\epsilon^2} \cdot \{[\alpha^s(z)(\lambda(z)/\lambda)\sigma_\epsilon^2]m_t^u + [\sigma_u^2 + \alpha^d(z)(\lambda(z)/\lambda)\sigma_\epsilon^2]\epsilon_t^s(z) + [\alpha^s(z)(\lambda(z)/\lambda)\sigma_\epsilon^2]\epsilon_t^d(z)\}.$$

Equation (17) can be readily interpreted: only the unperceived, not the perceived, component of the current money supply growth has an impact on the market output. The unperceived part of the money supply affects output because of its effect on relative prices. The perceived part of money supply does not affect output because it has no impact on relative prices. Output also responds to market-specific supply and demand shocks.

Test Procedures

The object of this section is to describe the methodology employed in the joint estimation procedure and NRH tests. The specification used to generate the optimal growth rate of the policy variable given in (3) is represented by the forecast equation:

$$(18) \quad m_t = X_{t-1}\gamma + m_t^u,$$

where X_{t-1} is a vector of variables (information set available at $t-1$) used to forecast the money supply growth, γ is the corresponding coefficient vector, and m_t^u is the random term, which is assumed to be generated by a temporally independent white noise process. Specifically, $X_{t-1}\gamma$ represents the anticipated money growth, m_t^e, and m_t^u represents the unanticipated money growth.

For the purpose of empirical analysis, the output equation (17) can be represented as:

$$(19) \quad y_t(z) = \theta + \sum_{i=0}^{n} \beta_i m_{t-i}^u + \epsilon_t,$$

where θ and β_i ($i = 0, 1, \ldots, n$) are coefficients. To test the neutrality proposition, equation (19) is modified to include the expected money supply growth as:

$$(20) \quad y_t(z) = \theta + \sum_{i=0}^{n} \beta_i m_{t-i}^u + \sum_{i=0}^{n} \delta_i m_t^e + \epsilon_t.$$

The neutrality test is conducted by testing $\delta_i = 0$ for all i's in equation (20). Earlier studies (Barro 1977, 1978; Barro and Rush) used a two-step procedure to test the NRH. In this procedure, the money forecasting equation is estimated by using ordinary least squares (OLS), and the predicted and residual series from this regression are used, respectively, as the anticipated and unanticipated money supply growth in the output equation which is also estimated by OLS. Mishkin points out that if the population covariances between the parameters across the money and output equations are nonzero, the two-stage estimates are not efficient and also the test statistics are invalid. In this study, following Mishkin, the joint estimation procedure is used. The joint estimation procedure estimates the money forecasting equation and output equation as a simultaneous nonlinear system.[4] Since this procedure allows for covariances between parameters across equations, the estimates are efficient and the test statistics also are valid. The joint estimation procedure involves nonlinear estimation of the constrained system, (18) and (19), as well as the unconstrained system, (18) and (20). In the constrained system the restriction all $\delta_i = 0$ is imposed, whereas in the unconstrained system this restriction is not imposed. For each system, the output and

[4] Nonlinear estimation is employed in this study because it easily implements the covariance restriction and degrees of freedom correction, which leads to more credible likelihood ratio test statistics. See Mishkin for further details of nonlinear estimation and its advantage over traditional full information maximum likelihood estimation.

the forecast equations are estimated jointly by imposing the restriction that the parameter vector, γ, is equal in the two equations. Following the test procedure described in Mishkin, the likelihood ratio statistic for the neutrality proposition is expressed as:

$$(21) \qquad V = 2N \log(SSR^c/SSR^u),$$

where N is the number of observations in each equation, SSR^c is the sum of squared residuals from the constrained system, and SSR^u is the sum of squared residuals from the unconstrained system. The test statistic, V, is asymptotically distributed as $\chi^2(q)$ under a null hypothesis that all $\delta_i = 0$, where q is the total number of restrictions imposed.

Empirical Analysis

In this section the empirical results estimated on the basis of the theoretical model described in the previous two sections are presented. First, the specification and estimation of the forecast equation for the policy variable are discussed. Second, the results on the effects of perceived and unperceived components of the policy variable on farm output are presented.

The results of OLS estimation of money growth and joint estimation of farm output are reported in this section. The quarterly data for the farm sector real gross domestic product (GDP) comes from the *National Income and Product Accounts of the United States* and various issues of the *Survey of Current Business* published by the U.S. Department of Commerce. The data for the money supply and the three-month treasury bill rate are from the St. Louis Federal Reserve Bank, and the unemployment rate is from International Financial Statistics, International Monetary Fund. The data period covers 1965:1 to 1987:4.

Money Supply Growth Equation

Since an appropriate money forecasting equation should be based on all the available information, the money supply growth was regressed on its own past values and other pertinent monetary policy response macrovariables. These macrovariables include real gross national product (GNP) growth, three-month treasury bill rate, inflation rate, nominal GNP growth, M1 money supply growth, unemployment rate, government deficit, real government expenditure, and balance of payments on current accounts. Four lags were chosen for each of these variables because it prevents the researchers from searching for alternative specifications that would produce results confirming any priori belief. The procedure used to determine the significance of these variables in the money forecast equation is multivariate Granger (1969) tests. An F-test under the null hypothesis that four coefficients of the individual policy response variables are jointly zero was carried out. On the basis of this criterion, the lagged money supply growth, the three-month treasury bill rate, and the unemployment rate were included in the forecast equation.

Many of the earlier studies do not account for changes over the years in the monetary policy procedures or the expectations process. Gauger (1988) indicates that failure to take the changes into account leads to misspecification of the anticipated and unanticipated money supply growth and may distort neutrality implications. In this study money forecasting equations are specified to allow for the well-known change in the Federal Reserve Operating Procedures in 1979:4 and the significant change that occurred in the weight placed on the interest rate and money growth information in 1975:1. Specifically, the money forecasting equation allows for changes in the slope coefficients of the interest rate at 1975:1 and 1979:4.[5]

The OLS estimates of the money supply growth equation based on quarterly data from 1965:1 to 1987:4, with standard errors in parentheses, are

$$(22) \quad m_t = \underset{(.009)}{.0108} + \underbrace{\underset{(.111)}{.5901 m_{t-1}} - \underset{(.1166)}{.081 m_{t-2}} + \underset{(.0985)}{.0157 m_{t-3}} - \underset{(.0858)}{.0021 m_{t-4}}}_{F(4,72) = 8.56}$$

[5] Slope coefficients of lagged money growth terms at 1975:1 and 1979:4 were not significant.

$$
\underbrace{- \underset{(.0012)}{.0048TB_{t-1}} + \underset{(.0018)}{.0084TB_{t-2}} - \underset{(.0019)}{.0057TB_{t-3}} + \underset{(.0017)}{.0013TB_{t-4}}}_{F(4,72) = 6.59}
$$

$$
\underbrace{+ \underset{(.0007)}{.0002TB_{t-1}*D1} - \underset{(.0009)}{.0027TB_{t-2}*D1} + \underset{(.0011)}{.0056TB_{t-3}*D1} - \underset{(.0010)}{.0031TB_{t-4}*D1}}_{F(4,72) = 7.07}
$$

$$
\underbrace{+ \underset{(.001)}{.0001TB_{t-1}*D2} + \underset{(.001)}{.001TB_{t-2}*D2} - \underset{(.001)}{.003TB_{t-3}*D2} - \underset{(.001)}{.0027TB_{t-4}*D2}}_{F(4,72) = 2.38}
$$

$$
\underbrace{- \underset{(.0215)}{.0387UN_{t-1}} + \underset{(.0323)}{.0847UN_{t-2}} - \underset{(.0318)}{.0444UN_{t-3}} - \underset{(.0190)}{.0012UN_{t-4}}}_{F(4,72) = 1.85}
$$

$$
R^2 = .70, \quad \hat{\sigma} = .00004, \quad \mathrm{DW} = 1.94,
$$

where m_t = growth rate of M1 money supply, TB = three-month treasury bill rate, UN = log of unemployment rate, $D1$ = zero from 1965:1 to 1979:3 and one thereafter, $D2$ = zero from 1965:1 to 1974:4 and one thereafter, $\hat{\sigma}$ = standard error of estimate, and DW = Durbin-Watson statistic.

The F-statistics reported in equation (22) test the explanatory power of the four lagged values of each variable in predicting the money supply growth. The approximate critical value of the F-statistics at the 5% level is 2.50 and at the 1% level is 3.60. Four lagged values of money supply growth, the treasury bill rate, and the 1979 change in the expectation process (as reflected by $TB*D1$) are significant at the 1% level. Four lagged values of money growth capture the persistence effects not explained by other independent variables. The treasury bill rate captures the policy changes in the money supply pursued by the Fed in response to interest rate changes. The change in expectations in 1975 is marginally significant. The coefficients of the lagged unemployment rate reflect the counter cyclical response of money growth. The unemployment rate is included to maintain a tie to the money forecasting specification in the original Barro (1977) study and numerous other neutrality studies.[6] The specification employed for the money forecasting equation in (22) is used in the joint estimation procedure.

Farm Output Equation

The empirical results from the tests of NRH and the impacts of the anticipated and unanticipated money supply growth rates on farm output are the focus of this subsection.[7] The farm output equation is jointly estimated with the forecasting equation as explained in the previous section.

In pursuit of robustness of results, the neutrality tests were conducted with 4, 8, 12, and 16 quarters of anticipated and unanticipated money supply growth rates in the output equation.[8] Likelihood ratio tests were conducted to test the NRH [the significance of the anticipated money supply growth (m^e)] and also the significance of the unanticipated money supply growth (m^u). Results of these tests are summarized in table 1. The neutrality models im-

[6] The unemployment rate is significant in the money forecast equations estimated by Barro (1978), and Barro and Rush. However, their money forecast equations do not include interest rates. In the money forecast estimation in this study, the unemployment rate is no longer significant at the 5% level when the interest rate is included as an information source.

[7] It is common in the macroeconomics literature to test the NRH at the sectoral level, not at the individual market level, though the empirical results hinge upon aggregation bias.

[8] Previous studies reveal that money neutrality results are influenced by the lag lengths of anticipated and unanticipated money supply growth in the output equation (see Mishkin).

Table 1. Likelihood Ratio Test Statistics for Impacts of Anticipated and Unanticipated Money Supply Growth. Model: $y_t(z) = \theta + C_1T + C_2D83 + \sum_{i=0}^{n} \beta_i m^u_{t-i} + \sum_{i=0}^{n} \delta_i m^e_t + \epsilon_t$

	Anticipated Money Growth	Unanticipated Money Growth
4-quarter model ($n = 3$)	$\chi^2(4) = 52.364$	$\chi^2(4) = 52.168$
8-quarter model ($n = 7$)	$\chi^2(8) = 84.098$	$\chi^2(8) = 82.770$
12-quarter model ($n = 11$)	$\chi^2(12) = 138.336$	$\chi^2(12) = 133.906$
16-quarter model ($n = 15$)	$\chi^2(16) = 176.320$	$\chi^2(16) = 163.829$

Note: The null hypothesis for the tests on anticipated and unanticipated money growth, respectively: H_0 all $\delta_i = 0$, $i = 0, 1, \ldots, n$; and H_0 all $\beta_i = 0$, $i = 0, 1, \ldots, n$. Critical values of χ^2 at the 1% significance level are $\chi^2(4) = 13.277$, $\chi^2(8) = 20.090$, $\chi^2(12) = 26.217$, and $\chi^2(16) = 32.0$.

ply that only m^u will have significant impacts on real sectoral output. However, likelihood ratio tests show that not only m^u but also m^e have significant impacts on farm output. This is true in both the short- and long-lag length models since χ^2 statistics are significant at the 1% level in all cases. Thus, the test results do not support the NRH.

Even though agriculture is typically viewed as a relatively flexible price sector (see Bordo), one needs to focus on the movements of the prices received by farmers. Farm policy programs such as loan rates and Farmer Owned Reserve restrict the movements of prices received by farmers and thus introduce rigidity into agricultural output prices. These programs stabilize the nominal prices of some commodities within upper and lower price bounds and thus limit the movements of nominal prices to any exogenous shocks such as money supply shocks. For example, Rausser et al. note that there is an asymmetry in the effect of monetary policy on agricultural markets because of U.S. agricultural policies which support prices for major commodities. Stabilization of nominal prices is expected to cause large movements in relative prices. As shown by Phelps and Taylor and by Gauger (1984), the anticipated money supply growth will have real impacts if output prices are less flexible relative to input prices.

Since the results of the likelihood ratio tests are similar for various lag specifications and because of space limitations, only the results of the output equation with 12 quarters m^e and m^u are reported in table 2.[9] In the output equation, in addition to the money supply growth variables, a time trend (T) and a dummy variable for four quarters in 1983 ($D83$) are included. The dummy variable captures the impacts of a severe drought in 1983. The estimates of fourth-order autocorrelation coefficients also are reported in table 2.[10] Major interest is in the estimates of the β_i and δ_i coefficients, which reflect the impacts of the anticipated and unanticipated money supply

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[9] For readers curious about the forecasting equation in the joint estimation procedure, the estimated money supply growth equation for the unconstrained system, with standard errors in parentheses, is

$$
\begin{aligned}
m_t = & -\underset{(.004)}{.0039} \\
& + \underset{(.1699)}{.7196}m_{t-1} + \underset{(.1691)}{.1693}m_{t-2} + \underset{(.1282)}{.5366}m_{t-3} - \underset{(.1271)}{.0311}m_{t-4} \\
& - \underset{(.0008)}{.0045}TB_{t-1} + \underset{(.0017)}{.0098}TB_{t-2} - \underset{(.0018)}{.0077}TB_{t-3} \\
& + \underset{(.0011)}{.0039}TB_{t-4} + \underset{(.0004)}{.0003}TB_{t-1}{\cdot}D1 - \underset{(.0009)}{.0029}TB_{t-2}{\cdot}D1 \\
& + \underset{(.0009)}{.0051}TB_{t-3}{\cdot}D1 - \underset{(.0006)}{.0033}TB_{t-4}{\cdot}D1 - \underset{(.0006)}{.0003}TB_{t-1}{\cdot}D2 \\
& + \underset{(.0011)}{.0002}TB_{t-2}{\cdot}D2 - \underset{(.0011)}{.0001}TB_{t-3}{\cdot}D2 + \underset{(.0007)}{.0002}TB_{t-4}{\cdot}D2 \\
& - \underset{(.0140)}{.0401}UN_{t-1} + \underset{(.0287)}{.0719}UN_{t-2} - \underset{(.0271)}{.0656}UN_{t-3} \\
& + \underset{(.0123)}{.035}UN_{t-4}.
\end{aligned}
$$

The variable definitions are as given in the text. The performance of this equation is better than the OLS equation because of the "information crossovers" between the output and the forecast equations. Because of space limitations, the estimates of the constrained system are not reported.

[10] In order to obtain valid test statistics to test the neutrality proposition, it is important to avoid spurious regression phenomena. Therefore, very careful consideration is given to the serial correlation properties of the residuals to ensure that residuals are white noise. The output equation is corrected for a fourth-order serial correlation, which generally is sufficient to ensure white noise in the residuals when quarterly data are used.

Table 2. Nonlinear Joint Estimates of Output Model with Twelve Quarters of Monetary Variables. Model: $y_t(z) = \theta + C_1T + C_2D83 + \sum_{i=0}^{11} \beta_i m^u_{t-i} + \sum_{i=0}^{11} \delta_i m^e_t + \epsilon_t$

$\hat{\theta} = 4.163(22.93)$	$\hat{C}_1 = 0.025(3.38)$	$\hat{C}_2 = -0.198(-5.08)$	
$\hat{\beta}_0 = 0.535(0.53)$		$\hat{\delta}_0 = -4.867(-3.02)$	
$\hat{\beta}_1 = 5.083(2.81)$		$\hat{\delta}_1 = -7.123(-3.34)$	
$\hat{\beta}_2 = 7.650(2.16)$		$\hat{\delta}_2 = -4.422(-1.60)$	
$\hat{\beta}_3 = 11.296(2.45)$		$\hat{\delta}_3 = 1.806(0.46)$	
$\hat{\beta}_4 = 10.550(2.23)$		$\hat{\delta}_4 = 7.566(1.72)$	
$\hat{\beta}_5 = 10.382(2.38)$		$\hat{\delta}_5 = 6.285(1.53)$	
$\hat{\beta}_6 = 8.474(2.49)$		$\hat{\delta}_6 = 5.185(1.67)$	
$\hat{\beta}_7 = 4.980(1.76)$		$\hat{\delta}_7 = -0.009(-0.00)$	
$\hat{\beta}_8 = 5.555(2.30)$		$\hat{\delta}_8 = 0.842(0.37)$	
$\hat{\beta}_9 = 6.315(2.64)$		$\hat{\delta}_9 = 1.801(0.76)$	
$\hat{\beta}_{10} = 4.224(1.86)$		$\hat{\delta}_{10} = 5.589(2.32)$	
$\hat{\beta}_{11} = 1.292(0.75)$		$\hat{\delta}_{11} = 3.472(1.93)$	
$\hat{\rho}_1 = -0.0034(-0.03)$	$\hat{\rho}_2 = -0.200(-1.75)$	$\hat{\rho}_3 = -0.524(-5.31)$	$\hat{\rho}_4 = 0.027(0.23)$
	$\hat{\sigma}^2 = 0.00168$		
$\sum_{i=0}^{11} \hat{\beta}_i = 76.336$		$\sum_{i=0}^{11} \hat{\delta}_i = 16.125$	

Note: The values in parentheses are t-statistics. Critical values of the approximate t-statistics are as follows: $t_{.05,132} \approx 1.98$ and $t_{.01,132} \approx 2.617$.

growth, respectively. The coefficients of m^e indicate that the anticipated money growth has negative impacts on farm output in the first three quarters. It is also interesting to note that negative impacts of m^e primarily are confined to the first three quarters, and the rest of the coefficients are not significant with the exception of $\hat{\delta}_{10}$ Thus, the anticipated money growth has adverse impacts but cuts off relatively quickly.

The negative impacts of the anticipated money supply growth in the first three quarters may be related to the differing degree of stickiness of output prices and input prices. Even though agriculture is characterized as a sector with flexible output prices, one needs to examine whether prices received by farmers are more or less flexible relative to prices paid by farmers. As already explained, agricultural programs impart some rigidity to the prices received by farmers, whereas prices paid by farmers for inputs such as fertilizer, pesticides, and machinery may vary over the period.[11] As shown by Gauger (1984), the anticipated money supply growth will have negative impacts on real output if output prices are relatively less flexible than input prices. For nominal movements associated with the currently anticipated portion of money growth, the producer may realize he or she is temporarily caught in a rigid price/flexible costs squeeze. He or she cannot totally escape the significant negative impacts, but makes the adjustments possible (such as reduced input use) to confine the negative impacts to a relatively short period. Thus, the m^e impacts are negative and short lived.

If only the significant $\hat{\delta}_i$ coefficients are considered, the net effect of anticipated money supply growth is negative. Furthermore, the significant impacts of the anticipated money supply growth occur immediately as evidenced from the significant $\hat{\delta}_0$ and $\hat{\delta}_1$. The impacts in the later periods are not significant (except for $\hat{\delta}_{10}$). For models with 4, 8, and 16 quarters of m^e and m^u in the output equation, the pattern of m^e impacts is very similar. The negative effects of anticipated money supply growth have a triangular shape, with the largest effect appearing after the current period. The contemporaneous and two-period lag effects are of roughly equal size. The pattern of output response indicates that the effect of the rigid price/flexible costs squeeze peaks after the current period, but after two periods farmers are able to make adjustments in input use to reduce the negative effect of anticipated money supply growth.

[11] However, it should be emphasized that this study does not imply that agricultural output prices are not overshooting their long-run equilibrium levels.

Unlike the m^e impacts, m^u impacts are positive, significant, and spread over a longer time. This pattern of impacts is related to the source of unanticipated money supply shocks. Unanticipated money supply growth is misinterpreted as market-specific shocks because market participants with imperfect information cannot distinguish between aggregate and market-specific shocks. As a result, m^u interferes with market signals, and nominal movements associated with m^u are misinterpreted as relative price changes associated with a shift in demand. Thus, producers may respond with substantive changes in production abilities whose impacts persist over longer periods. The positive impacts of m^u are consistent with the findings of Starleaf, Meyers, and Womack. They conclude that an unanticipated increase in the growth rate of nominal aggregate demand benefits farmers. They also correctly emphasize that farmers have been beneficiaries of the unanticipated, but not the anticipated, increase in the rate of inflation.

The impacts of the current unanticipated money supply growth are not significant, i.e., the estimate of the β_0 coefficient is relatively small and not significant. The statistically significant impacts of the unanticipated money supply growth begin after a one-period lag and persist over several periods. The insignificant impact of the current unanticipated money supply growth can be attributed to the fact that production in the agricultural sector is not instantaneous. Thus, even if farmers make production adjustments instantly in response to the misinterpreted relative price changes, the effect on the output is realized with a one-period lag. The neutrality proposition indicates that the relative magnitudes of coefficients of m^e and m^u are such that coefficients of m^e are insignificant and less than those of m^u. However, the empirical estimation shows that the impacts of m^e are greater (in absolute value) than those of m^u in some cases.

Summary and Implications

According to the monetary neutrality hypothesis, only the unanticipated money supply growth has impacts on real economic variables, and the anticipated money supply growth has no real impacts. However, Fischer; Phelps and Taylor; and Gauger (1984) show that, if nominal price rigidities exist, then the anticipated money supply growth will affect real economic variables. In this study the monetary neutrality hypothesis is tested on real farm output. The test procedure involves a joint estimation of real farm output and money supply growth equations. The empirical results show that the anticipated money supply growth does have significant effects on farm output and, thus, do not support the money neutrality hypothesis. The significant impacts of the anticipated money supply growth are confined to the first year and cut off relatively quickly as farmers make adjustments in their production decisions to limit the adverse impacts to a relatively short period, whereas the significant impacts of the unanticipated money supply growth persist over several periods as farmers misinterpret the nominal movements associated with the unanticipated money supply growth as relative price changes associated with the demand shift.

Furthermore, as pointed out by Blinder and Mankiw, aggregate analysis of monetary neutrality tests can mask the true impacts of monetary policy in a specific sector. The empirical results support this view, i.e., the anticipated money growth may have a nonneutral impact on a particular sector. The implication of this result is that since the agricultural sector, in contrast to some other sectors, is subject to differential impacts of monetary policy shocks, analysis of agricultural market dynamics should take into account the effects of monetary policy. Also, farm policy decision makers should consider monetary shocks in formulating price support and storage policies. This is particularly important in view of increased integration between the farm and nonfarm sectors. Thus, macroeconomic disturbances are vital to agricultural policy developments.

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References

Azzam, A., and E. Pagoulatos. "Unanticipated Money Growth and Livestock Supply Decisions." Paper presented at the American Agricultural Economic Association meeting, Iowa State University, Ames IA, 1985.

Barro, R. J. "Rational Expectations and the Role of Monetary Policy." *J. Monetary Econ.* 2(1976):1–32.

———. "Unanticipated Money Growth and Unemployment in the United States." *Amer. Econ. Rev.* 67(March 1977):101–15.

———. "Unanticipated Money, Output, and the Price Level in the United States." *J. Polit. Econ.* 86(1978): 549–80.

Barro, R., and M. Rush. "Unanticipated Money and Economic Activity." *Rational Expectations and Economic Policy,* ed., S. Fischer, pp. 23–48. Chicago: University of Chicago Press (for NBER), 1980.

Bessler, D. A. "Relative Prices and Money: A Vector Autoregression on Brazilian Data." *Amer. J. Agr. Econ.* 66(1984):25–30.

Blinder, A., and N. G. Mankiw. "Aggregation and Stabilization Policy in a Multicontract Economy." *J. Monetary Econ.* 13(1984):67–86.

Bordo, M. D. "The Effects of Monetary Change on Relative Commodity Prices and the Role of Long-Term Contracts." *J. Polit. Econ.* 88(1980):1088–109.

Cairnes, J. E. *Essays on Political Economy: Theoretical and Applied.* London: Macmillan & Co., 1873.

Chambers, R. G. "Agricultural and Financial Market Interdependence in the Short Run." *Amer. J. Agr. Econ.* 66(1984):12–24.

Devadoss, S., and W. H. Meyers. "Relative Prices and Money: Further Results for the United States." *Amer. J. Agr. Econ.* 69(1987):838–42.

Enders, W., and B. Falk. "A Microeconomic Test of Money Neutrality." *Rev. Econ. and Statist.* 66(1984):666–69.

Fischer, S. "Long-Term Contracts, Rational Expectations, and the Optimal Money Supply Rule." *J. Polit. Econ.* 85(1977):191–205.

Gardner, B. "On the Power of Macroeconomic Linkages to Explain Events in U.S. Agriculture." *Amer. J. Agri. Econ.* 63(1981):871–78.

Gauger, J. "Anticipated Money and Production with Rigidities in Output Prices or Purchased Input Costs." Unpublished Ph.D. dissertation, Iowa State University, 1984.

———. "Disaggregated Level Evidence on Monetary Neutrality." *Rev. Econ. and Statist.* 70(1988):676–80.

Granger, C. W. J. "Investigating Causal Relations by Econometric Models and Cross-Spectral Methods." *Econometrica* 37(1969):424–38.

Grennes, T., and J. S. Lapp. "Neutrality of Inflation in the Agricultural Sector." *J. Int. Money and Finance* 5(1986):231–43.

Hercowitz, Z. "Money and the Dispersion of Relative Prices." *J. Polit. Econ.* 89(1981):328–56.

Lucas, R. E., Jr. "Expectations and the Neutrality of Money." *J. Econ. Theory* 4(April 1972):103–24.

———. "Some International Evidence on Output-Inflation Tradeoffs." *Amer. Econ. Rev.* 63(1973):326–34.

Mishkin, F. S. "Does Anticipated Monetary Policy Matter? An Economic Investigation." *J. Polit. Econ.* 90(1982):22–51.

Orden, D. "Money and Agriculture: The Dynamics of Money-Financial Market-Agricultural Trade Linkages." *Agr. Econ. Res.* 38(1986):14–28.

Phelps, E. S., and J. B. Taylor. "Stabilizing Powers of Monetary Policy under Rational Expectations." *J. Polit. Econ.* 85(1977):163–90.

Rausser, G. C., J. A. Chalfant, H. A. Love, and K. G. Stamoulis. "Macroeconomic Linkages, Taxes and Subsidies in the U.S. Agricultural Sector." *Amer. J. Agr. Econ.* 68(1986):399–412.

Robertson, J. C., and D. Orden. "Monetary Impacts on Prices in the Short and Long Run: Some Evidence from New Zealand." *Amer. J. Agr. Econ.* 72(1990): 160–71.

Saunders, P. J. "Causality of U.S. Agriculture Prices and the Money Supply: Further Empirical Evidence." *Amer. J. Agr. Econ.* 70(1988):588–96.

Saunders, P. J., and D. Bailey. "Effects of Monetary Changes on the Price Level and Output in the U.S. Agricultural Sector." *Agr. Finance Rev.* 46(1986):58–68.

Starleaf, D. R., W. H. Meyers, and A. W. Womack. "The Impact of Inflation on the Real Income of U.S. Farmers." *Amer. J. Agr. Econ.* 67(1985):384–89.

U.S. Department of Commerce. *Survey of Current Business.* Various issues, Washington DC.

———. *The National Income and Product Accounts of the United States Statistical Tables, 1929–82.* Washington DC, 1986.