DO PRICES LEAD MONEY? A REEXAMINATION OF THE NEUTRALITY HYPOTHESIS

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In one class of theoretical models, real effects occur only if changes in money growth are expected to occur in some future period, if expected in the current period, they are neutral. Some empirical models examine the neutrality of expected current money growth and therefore do not directly address the neutrality of expected future growth. This paper develops an empirical model that explicitly incorporates expected future changes in money growth. A reexamination of the rationality, neutrality, and macro-rational expectations hypotheses over a sample of four countries suggests that the use of expected future money growth results in strong rejections of the neutrality hypothesis.

I. INTRODUCTION

The revolution in macroeconomics inspired by the theory of rational expectations called into question the ability of systematic monetary policy to affect real economic variables. Much research has been devoted to the issue of policy effectiveness in the last decade and many examples have been constructed that demonstrate the theoretical possibility of nonneutrality even when expectations are formed rationally. One result of this research has been to demonstrate that the expectation of a future change in the money growth rate can cause a change in the current value of real output. In these models, an expected change in money growth at some point in the future results in a change in the price level in all time periods prior to the change in the money growth rate. This phenomenon of "prices leading money" see Brock [1974, 751] results in a change in real money balances in each time period prior to the expected change in the money growth rate, and the change in real money balances results in nonneutral changes in real output.

In order for the nonneutrality result to hold in this class of models, it is essential that the expected change in money growth be in some future time period so that prices, and hence real balances, change prior to the change in the money growth rate. When the change in money growth is expected to occur in the current time period rather than in the future, prices and the money supply change proportionately, leaving the value of real balances unchanged. In this case, there is no change in real output. This difference in the theoretical predictions concerning the neutrality of expected future and expected current changes in the money growth rate has implications for

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empirical tests of the neutrality hypothesis. According to these models, such
tests ought to examine the significance of the relationship between the current
value of real output and expected future changes in money growth. Tests of
the neutrality hypothesis performed in the past, such as those by Barro [1977;
1978], Mishkin [1982; 1983], and Hoffman and Schlagenhaufen [1982], have
examined the significance of the empirical relationship between the current
value of real output and the expected current money growth rate. Thus, these
tempirical models do not capture the crucial distinction between current and
future changes in money growth rates. This paper develops an empirical
model based on expected future rather than expected current changes in the
money growth rate in the real output equation, and then reexamines the
neutrality hypothesis.

The issue of whether expectations are formed rationally is also important
in the analysis of the empirical evidence for the neutrality hypothesis. As
Mishkin [1982; 1983] points out, the neutrality hypothesis has little meaning
without a theory of expectation formation. In light of this, tests of the
rationality hypothesis, as well as the joint hypothesis of rationality and
neutrality known as the macro rational expectations hypothesis1 (MRE), are
also conducted.

II. THEORETICAL MODELS OF NONNEUTRAL MONEY

In many equilibrium rational expectations models, the neutrality of money
depends upon whether an expected change in the money supply is in the
current or some future time period. For example, consider the model of
Fischer [1979]. In this model, an anticipated increase in the rate of inflation
due to an increase in the money stock reduces the expected real return on
money held as an asset and, through the Tobin effect, induces a portfolio
shift from money into capital. Since output is an increasing function of the
capital stock, the increase in capital results in an increase in output. There-
fore, any change in the money stock that changes the anticipated inflation
rate has real effects in Fischer's model.

Fischer examines movements of the anticipated inflation rate due to per-
manent and transitory changes in the money stock. In the empirical section
below, the money growth rate is assumed to follow an autoregressive process.
This implies that all innovations to the money growth rate are transitory in
the long run. Thus, Fischer's results concerning transitory changes in money
growth are of interest here. However, Fischer examines changes in the money
stock rather than money growth. Fortunately, this is easily overcome since
a permanent change in the money stock is equivalent to a transitory change.

1. The MRE hypothesis, which is due to Modigliani [1977], states that if expectations are
formed rationally in a natural rate model, then anticipated changes in the money supply are neutral.
It is therefore a joint hypothesis composed of the individual hypotheses of neutrality and rationality.
According to these models, such a relationship between the current changes in money growth. Tests of such, such as those by Barro [1977; 1979] and Schlagenhauf [1982], have led to a relationship between the current money growth rate. Thus, these distinction between current and short-run develops an empirical relationship between current changes in the inflation, and then reexamines the

rationality is also important in the neutrality hypothesis. As rationality hypothesis has little meaning in light of this, tests of the hypothesis of rationality and expectations hypothesis (MRE), are

Impossible, Money

s models, the neutrality of money in the money supply is in the example, consider the model of d increase in the rate of inflation the expected real return on stock, induces a portfolio is an increasing function of the in an increase in output. There, changes the anticipated inflationary stock. In the empirical section follow an autoregressive process. Money growth rate are transitory inning transitory changes in money or examines changes in the money stock, this is easily overcome since equivalent to a transitory change in money growth. Thus, only Fischer’s results concerning permanent changes in the money stock are discussed here.

Now consider Fischer’s results. He finds that anticipated permanent changes in the money stock are nonneutral, but unanticipated permanent changes are neutral. Stated in terms of money growth rates, anticipated transitory changes in money growth, which change expected inflation rates in time periods prior to the change in money growth, cause a portfolio reallocation from money assets into capital, and nonneutrality results. This is not the case for unanticipated transitory changes in money growth. When the change in money growth is unanticipated, the price level rises in the current time period in proportion to the rise in the money stock. This results in an increase in the current inflation rate, but does not change the expected inflation rate for the next time period. Since the Tobin effect depends upon the expected inflation rate, and not on the current rate of inflation, unanticipated transitory changes in money growth are neutral. In summary, anticipated transitory changes in money growth are nonneutral because they change the expected rate of inflation, while unanticipated changes, which change the current rate of inflation but do not change the expected rate of inflation, are neutral.

Another example of this type of nonneutrality can be found in the work of Brock [1974; 1975]. In Brock’s model, a representative agent with perfect foresight maximizes the present discounted value of the additively separable utility of consumption, leisure, and real money balances subject to the constraint that, in each time period, current consumption plus the change in money demand from the previous period equals income plus money transfers.

Consider an anticipated transitory increase in money growth. When the representative agent is notified of a transitory increase in money growth, the future increase in money transfers is discounted back to the current time period and, at the old expected price path, the agent feels wealthier and attempts to purchase more goods. This causes prices to rise faster than previously and, since the current stock of money has not changed (the change in money growth is at some future date) and prices have risen, real money balances must fall.

In subsequent time periods, this process is repeated; but at each point in time the rise in prices and the fall in real balances are larger than in the previous time period. This is because the future increase in money transfers is discounted over one less time period, which leads to a larger increase in wealth and a larger increase in the demand for goods. In the time period

2. To see this, suppose that the money stock is 100 for all time periods through $t^*$ and 110 in all time periods thereafter. The money growth rate is 1.0 until $t^*$, 1.10 at time $t^*+1$, and 1.0 in all subsequent time periods, so that a transitory change in money growth has occurred at time $t^*+1$.

3. Actually, Brock considers only anticipated permanent changes in money growth. The extension to anticipated and unanticipated transitory changes in money growth is relatively straightforward.
when the change in money growth actually occurs, the whole process is reversed. Since the change in money growth realized in the current time period is transitory, the agent will anticipate a decline in money growth in the next time period. Based on the feeling that income will be lower, the demand for goods declines, causing prices to rise slower than previously, a new equilibrium is attained where real money balances are the same as before the announcement of the transitory change in money growth. Summarizing, in the time period when the transitory change is announced, real balances begin falling and continue to fall at an increasing rate until the time period where the change in money growth actually occurs. In subsequent time periods, real balances return to their original level. Thus, the change in real balances is a short-run phenomenon. In the long run, real balances do not deviate from the steady state values attained prior to the change in money growth.4

The time path of other real magnitudes in the model can also be determined. Real consumption and labor remain unchanged at their steady state values over time because the utility and production functions are time stationary and because the real balance term is additively separable in the utility function. This additive separability dichotomizes the model into real and financial sectors so that changes in real balances do not affect other real magnitudes.5

Consider next an unanticipated transitory change in money growth. In this case, real money balances do not change. In the previous case, real money balances changed because prices changed prior to the actual change in money growth. This phenomenon of “prices leading money” does not occur when the change is unanticipated because the change in prices and money will be proportional. When the representative agent is the benefactor of an unanticipated increase in money growth, the demand for goods rises as before, causing upward pressure on prices. Prices then rise until the existing stock of money, which is higher than anticipated, is willingly held. This occurs when prices rise in proportion to the increase in the supply of money. In future time periods, the money growth rate is anticipated to be the same as in the past so that real money balances do not change in any time period. Thus, unanticipated transitory changes in money growth are neutral because expectations about the future remain unchanged. In summary, Brock’s [1974;

4. The following scenario may be helpful in interpreting this result. Consider the Vietnam war. During this period, it was widely believed that financing of the war would cause either an increase in the growth rate of money or an increase in taxes, despite Johnson’s claims to the contrary. Since Johnson was strongly opposed to tax increases, it was rational to expect increases in the money growth rate and to get out of nominal assets long before the increases in money growth were implemented.

5. The dichotomy inherent in the model resulting from the separability of real balances in the utility function can be overcome in a fairly straightforward manner. Thoma (1985) has shown how to relax this assumption without encountering the problem of multiple unstable equilibria usually associated with dropping separability (see Brock (1975) and Obstfeld (1984)).
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1975] model implies that anticipated future changes in money growth affect
the time path of real balances, while unanticipated changes do not. Stated
another way, expected current changes in money growth do not affect real
balances, only expected future changes matter.6

III. THE ECONOMETRIC MODEL

Much of the empirical work on the neutrality of money has concentrated
on the macro rational expectations (MRE) hypothesis. The MRE hypothesis
states that if expectations are formed rationally, then only unanticipated changes
in policy variables such as the money growth rate should matter in the
determination of real economic variables. The MRE hypothesis was initially
supported by the empirical work of Barro [1977; 1978], Barro and Rush
[1980], and Leiderman [1980]. However, questions concerning the validity
of these results were raised by Abel and Mishkin [1981] and Mishkin [1982;
1983]. They demonstrated that the statistical procedures used by these re-
searchers were inefficient and forced a key element of the MRE hypothesis,
the rationality of expectations, to be included as a maintained hypothesis
rather than a testable proposition.

Correction of the inefficiency problem and the incorporation of rationality
as a testable proposition resulted in conclusions that contradicted the support
for the MRE hypothesis evidenced in the earlier studies. In particular, Mish-
kin [1982; 1983], using data for the United States, and Hoffman and
Schlagenhauf [1982], using data for the United States and five additional
countries, found that the data do not support the hypothesis of neutrality,
only partially support the rationality of expectations, and reject the MRE
hypothesis.

The conclusions drawn by Mishkin [1982; 1983] and Hoffman and
Schlagenhauf [1982] are based mainly upon the results obtained from assum-
ing lag lengths of twenty and eleven respectively for the explanatory vari-
ables appearing in the output equation in their empirical models. When these
researchers assume the lag length to be seven, the evidence against the MRE
hypothesis, especially with respect to the rationality hypothesis, is not nearly
so strong.7

6. The results can also be stated in terms of expected inflation. For anticipated changes in
money growth, the expected rate of inflation first rises in anticipation of a higher money growth
rate, then falls back to its original level once the change in money growth has occurred. For
unanticipated changes, the expected rate of inflation remains unchanged in all time periods. This
interpretation makes clear the similarity between the results of Brock and Fischer. A recent paper
by Cooley and Hansen [1987] examines a model similar to Brock’s in an explicitly stochastic
environment and derives similar results. Expected inflation is nonneutral, but unexpected inflation
is not. The model of King [1982] comes to similar conclusions in a different framework.

7. The results obtained for the United States are illustrative. When the lag length is assumed
to be twenty and eleven by Mishkin [1982; 1983] and Hoffman and Schlagenhauf [1982] respec-
tively, the joint, neutrality, and rationality hypotheses are all rejected, which is unfavorable to
the MRE hypothesis in each instance. However, when the lag length is assumed to be seven, all
three of these hypotheses are accepted.
Mishkin [1982; 1983] and Hoffman and Schlagenauf [1982] explain the difference in results across assumed lag lengths by arguing that the shorter, seven-lag models are misspecified. Citing the work of Leamer [1978], they argue that the only cost of assuming long lag lengths is a potential reduction in the power of the hypotheses tests, making them less likely to reject the null hypothesis if it is false. The use of long lag lengths will not result in incorrect test statistics. However, the shorter lag assumption can result in invalid test statistics because the model is misspecified. Based upon this, they conclude that the failure to obtain rejections of the MRE hypothesis under the seven-lag specification in cases where rejections occur at longer lag lengths must be due to a misspecified model. Indeed, when discussing his results, Mishkin [1982, 33] remarks, “it appears that the shorter lag models are more favorable to the MRE hypothesis only because misspecification yields incorrect test statistics.”

This paper investigates a different potential misspecification of the empirical model suggested by the theoretical models in the previous section, the use of current rather than expected future changes in money growth in the empirical output equation. One interesting result of this change in the specification of the expectation terms is that the empirical model will no longer yield substantially different results when the lag length assumption is changed.

To illustrate, consider the empirical model of real aggregate output growth used in most previous empirical work.

\[
y_t = \bar{y}_t + \sum_{i=0}^{N} \beta_i (X_{t-i} - E_{t-1-i} X_{t-i}) + \sum_{i=0}^{N} \delta_i E_{t-1-i} X_{t-i} + e_t
\]

(7)

where \(y_t\) equals the growth of real output at time \(t\); \(\bar{y}_t\) equals the equilibrium or natural growth rate of output at time \(t\); \(N\) is the lag length of the output equation, \(X_t\) is an aggregate demand variable such as money growth, inflation, or nominal GNP growth; \(E_{t-1} X_t\) is the expected \(X_t\) conditional on all information dated \(t-1\) or earlier; \(\beta_i\) and \(\delta_i\) are coefficients; and \(e_t\) is an error term which might be serially correlated, but is not correlated with the right-hand side variables.

The \(\beta_i\) are the coefficients on the current and lagged values of unanticipated changes in the money growth rate. These terms are included based upon the theory of Lucas [1972] and the literature on adjustment costs. The expectation terms with the \(\delta_i\) coefficients are included to capture the effects that expected changes in the aggregate demand variable may have on real

8. This argument implicitly assumes that the “true” lag length lies between the assumed shorter and longer lag specifications.
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Schlagenhauf [1982] explain the gths by arguing that the shorter, te work of Leamer [1978], they lengths is a potential reduction in them less likely to reject the lag lengths will not result in er lag assumption can result in misspecified. Based upon this, sections of the MRE hypothesis where rejections occur at longer model. Indeed, when discussing 'it appears that the shorter lag the hypothesis only because misspecifica-
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\[ \sum_{i=0}^{N} \delta_i E_{t-1-i} X_{t-i} + e_t \]  

(7)

time \( t \); \( \bar{y}_t \) equals the equilibrium \( N \) is the lag length of the output s such as money growth, inflation, ected \( X_t \) conditional on all infor e coefficients; and \( e_t \) is an error it is not correlated with the right-
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output. In previous empirical work in this area, the theoretical justification for these terms has not been explicitly stated. They are simply included as a seemingly obvious alternative to the null hypothesis of neutrality.

Previous variations in the specification of the empirical output equation have concentrated mainly upon the definition of \( \bar{y}_t \), the natural growth rate of output, the lag length assumption, \( N \), and whether or not \( \delta_i \) is assumed to be zero for all \( i \). Little attention has been focused on trying different definitions of what constitutes anticipated money growth, that is, the appropriate expectation terms that ought to appear in the output equation. In the theoretical section, it was pointed out that the use of expected current money, \( E_{t-1} X_t \), and its lags does not accurately reflect the implications of a class of theoretical models of nonneutral money. The use of expected future money, \( E_{t-1} X_{t+1} \), and its lags in its place avoids this problem and results in cross-equation restrictions used in hypotheses tests that are quite different from the restrictions associated with the use of the term \( E_{t-1} X_t \). Accordingly, the model used in this paper is

\[ y_t = \bar{y}_t + \sum_{i=0}^{N} \beta_i (X_{t-i} - E_{t-1-i} X_{t-i}) + \sum_{i=0}^{N} \delta_i E_{t-1-i} X_{t-i+1} + e_t \]  

(8)

Rational expectations implies that anticipations of \( X_t \) and \( X_{t+1} \), the rate of money growth in the current period and one period ahead, will be formed optimally using all available information. The money growth equation used in previous work, e.g., Barro [1977; 1978], Hoffman and Schlagenhauf [1982], and Mishkin [1982; 1983], is

\[ X_t = Z_{t-1} \gamma + u_t \]  

(9)

where \( Z_{t-1} \) is a vector of variables available at time \( t-1 \) and useful in predicting \( X_t \); \( \gamma \) is a vector of coefficients, and \( u_t \) is an error term assumed to be uncorrelated with any information available at time \( t-1 \) (and is hence uncorrelated with the right-hand side variables). An optimal forecast of \( X_t \) is then

\[ E_{t-1} X_t = Z_{t-1} \gamma \]  

(10)

This variable and its lags were used to test the rationality and/or neutrality hypotheses in previous studies. The model estimated was (7) and (9). However, this particular single-equation specification for money growth cannot be used to obtain expectations of future money growth rates. If \( Z_{t-1} \) contains variables other than lagged \( X_t \), then in order to find the terms \( E_{t-1} X_{t+1} \) necessary to implement the model (8) a forecasting equation for each variable
appearing in the vector \( Z_{t-1} \) must be specified. This suggests the use of the more general vector-autoregressive (VAR) structure for the money-growth forecasting problem. Therefore, the money-growth specification assumed in this paper consists of the system of equations

\[
Z_t = \sum_{j=1}^{M} \Gamma_j Z_{t-j} + U_t
\]

(11)

where \( Z_{t-j} \) is a vector of variables useful in forecasting \( X_t \) as well as \( X_t \) itself; \( \Gamma_j \) is a matrix of coefficients for each \( j \); and \( U_t \) is a vector of error terms. The use of the VAR specification for money growth makes the model used here more general than previous single-equation specifications. For example, the model of output could easily be amended to include expectations of any or all of the exogenous variables in the current and future time periods. The empirical model used here truncates future expectations at one period ahead to avoid losing too many degrees of freedom.

One additional note concerning the VAR specification of money growth. As noted above, this specification cannot address the question of the effects of permanent changes in money growth. The stationary nature of the money-growth model used here implies that all innovations will eventually die out over time so that only temporary changes can be examined (see Mishkin [1983, 124]). Permanent changes in money growth involve changes in the coefficients of the forecasting model. The effects of such regime changes on the econometric tests of rationality and neutrality are discussed below.

The method of estimation involves joint, nonlinear estimation of the system (8) and (11), with \( X_t \) defined to be the money growth rate and \( y_t \) the growth of real output between \( t-1 \) and \( t \) (both variables are measured as the difference in the logs). The subjective expectations of agents are defined to be

\[
E_{t-\ell-1}^* Z_t = \sum_{j=1}^{M} \Gamma_j^* Z_{t-j}, \ i=0, 1, 2, \ldots
\]

(12)

and

\[
E_{t-\ell-1}^* Z_{t+1} = \sum_{j=1}^{M} (\Gamma_j^* + \Gamma_j^* 0) Z_{t-j}, \ i=0, 1, 2, \ldots
\]

(13)

where \( \Gamma_0^* = 0 \) is assumed for notational convenience. Note that \( E_{t-\ell-1}^* X_{t-\ell} \) and \( E_{t-\ell-1}^* X_{t-\ell+1} \) are the appropriate rows of \( E_{t-\ell-1}^* Z_{t-\ell} \) and \( E_{t-\ell-1}^* Z_{t-\ell+1} \) respectively.
The system of equations (8) and (11) embodies two sets of testable constraints which are of interest. The first is the neutrality hypothesis that the \( \delta_i = 0 \) for all \( i \). The second is the rationality hypothesis. This hypothesis states that

\[
E_{t-1-i}^* X_{t-i} = E_{t-1-i} X_{t-i} \quad \text{and} \quad E_{t-1-i}^* X_{t+i} = E_{t-1-i} X_{t+i}
\]

for all \( i \), where the right-hand side terms are the mathematical expectations implied by the VAR model of money growth and the left-hand side terms are the subjective expectations of agents as reflected in the output equation. The rationality hypothesis is tested by relaxing the cross-equation restrictions implied by (14), estimating the coefficients involved in the expectation terms separately in the output and money-growth equations, and then testing to see if the coefficients are equal.

The actual tests follow the procedure outlined by Mishkin [1982; 1983] generalized to incorporate the VAR money-growth specification and expected future changes in money growth used here. First, a likelihood ratio test of the joint hypothesis of rationality and neutrality, which is composed of (14) and \( \delta_i = 0 \) for all \( i \), is conducted by comparing the likelihood values of the constrained and unconstrained systems of equations. Next, a likelihood test of the neutrality hypothesis is performed under the maintained hypothesis of rationality. Finally the hypothesis of rationality is tested without imposing neutrality.

Estimation of the system (8) and (11) is carried out with joint nonlinear least squares. The procedure is as follows. Given an initial estimate for the variance-covariance matrix of residuals of the equations of the output and VAR money-growth equations, obtained from ordinary least squares estimates of the totally unconstrained system, estimate the system with nonlinear generalized squares (NGLS). A new \( \Sigma \) matrix is then estimated from the resulting residuals and the system is reestimated with NGLS. This iterative procedure is continued until there is little change (less than .01 percent) in the \( \Sigma \) matrix.

9. The test statistic is \( 2T[\ln(SSR_u) - \ln(SSR_c)] \) where SSR\(_u\) and SSR\(_c\) are the trace of the variance-covariance matrix of residuals for the constrained and unconstrained systems respectively. The statistic is asymptotically distributed as \( \chi^2(q) \), where \( q \) is the number of restrictions. The order of the tests is based upon the arguments of Mishkin [1983, 16–17].

10. Estimation will be conducted under the identifying restriction used in previous work on these issues, that the output equation constitutes a true reduced form. This assumption implies that the covariance of the error terms in the output and each of the VAR money growth equations in zero.

11. If this procedure is followed for estimating the constrained system, then the tests will be asymptotically valid. But as Mishkin [1983, 19] points out, the test statistics could be misleading in the small samples used here. Following Mishkin, the test statistics are corrected for the small sample problem as follows. The constrained system is estimated using the NGLS procedure described above, and the resulting \( \Sigma^c \) matrix from the constrained system is used to weight the NGLS estimates of the unconstrained system. For further details, see Goldfeld and Quandt [1972] or Mishkin [1983].
Before turning to the test results for the empirical model used here and a
discussion of these results, there are a few more estimation issues to discuss.
First, following Mishkin [1982; 1983], it is assumed that the error terms in
the output equation follow a fourth-order autoregressive process for three of
the countries examined here. However, in the fourth, a fifth-order process is
required to remove the serial correlation from the residuals. Second, two
specifications for the lag length, N, of the output equation will be examined,
a lag length of seven and a lag length of eleven. Third, the natural rate of
output growth, \( \bar{y}_n \), is modelled as a time trend as in Barro [1977; 1978],
Mishkin [1982; 1983], Hoffman and Schlagenhauf [1982], and others. Finally,
the coefficients on anticipated and unanticipated money, \( \beta_i \) and \( \delta_i \)
are constrained to lie along a fourth-order polynomial.

IV. THE RESULTS

In this section, tests of the MRE, rationality, and neutrality hypotheses
for each of the four countries are carried out. This is accomplished in two
steps. First, a set of multivariate Granger tests is used to determine the
specification of the VAR model of money growth for each country. Second,
the VAR model of money growth determined in the first step and the output
equation are estimated simultaneously for each country; tests of the MRE,
rationality, and neutrality hypotheses are conducted; and the results are dis-
cussed.

Specification of the Money Growth Forecasting Equations.

The VAR money growth equations will now be specified for each country
through the method suggested by Mishkin [1982; 1983]. The procedure is
essentially a set of multivariate Granger [1969] tests.

The multivariate Granger tests will be carried out over a set of macro-
economic variables that are of potential significance in predicting monetary
policy responses. The multivariate test involves regressing the money growth
rate on a constant, four lagged values of money growth, and four lagged
values of one of the variables from the list of possible monetary policy
response variables. An F-test under the null hypothesis that the set of coeffi-
cients on the individual policy response variables is zero is then carried

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12. Recent work by Lilien [1982] and Gray and Spencer [1985] indicates that specifying the
natural rate as a time trend may be too simplistic. The comments of Nelson and Plosser [1982]
and, more recently, Stock and Watson [1987] are also relevant. However, to retain comparability
with earlier studies, the time-trend specification will be adopted here.

13. The imposition of these constraints can help to avoid a small sample problem that may
arise in estimation. See Mishkin [1983, 112–14] for details and tests of the polynomial distributed
lag (PDL) restrictions. Additionally, the use of a PDL restriction can be useful in overcoming
any multicollinearity problems by reducing the dimension of the parameter space. See Judge et
al. [1980] for details.
empirical model used here and a core estimation issues to discuss. assumed that the error terms in a regression process for three of the fourth, a fifth-order process is from the residuals. Second, two output equation will be examined, eleven. Third, the natural rate of trend as in Barro [1977; 1978], Lagenhau [1982], and others.\textsuperscript{12} \(1\) unanticipated money, \(\beta_t\) and \(\delta_t\) polynomial.\textsuperscript{13}

LTS neutrality, and neutrality hypotheses out. This is accomplished in two tests is used to determine the growth for each country. Second, \(\phi_1\) in the first step and the output each country; tests of the MRE, conducted; and the results are dis-

Equations.

ow be specified for each country \[1982; 1983\]. The procedure is 969\] tests.

carried out over a set of macro-significance in predicting monetary variables regressing the money growth money growth, and four lagged ist of possible monetary policy hypothesis that the set of coef-variables is zero is then carried

tered [1985] indicates that specifying the comments of Nelson and Plosser [1982] relevant. However, to retain comparability adopted here. avoid a small sample problem that may ills and tests of the polynomial distributed, restriction can be useful in overcoming dition of the parameter space. See Judge et

out. If the F-test is significant at the 5 percent level, the variable is included in the set of regressors in the final money-growth system. The potential monetary response variables are

\[
\begin{align*}
M &= \text{the quarterly growth rate of money}, \\
P &= \text{the inflation rate}, \\
GNP &= \text{the growth rate of real gross national or domestic product}, \\
\text{NGNP} &= \text{the growth rate of nominal gross national or domestic product}, \\
U &= \text{the unemployment rate}, \\
G &= \text{real government expenditures}, \\
R &= \text{a short-term interest rate}, \\
D\text{EF} &= \text{the value of the government deficit}, \\
BPC &= \text{the balance of payments on current accounts position}, \\
\text{RES} &= \text{the value of external reserves}.
\end{align*}
\]

The data are for the four countries Canada, Germany, the United Kingdom, and the United States. The data are quarterly, seasonally adjusted, and the sample period is 1964:I to 1983:IV.\textsuperscript{14}

In Table I, the F-statistics for the joint significance of four lags of each potential monetary policy response variable are presented. In three of the countries, Germany, the United Kingdom, and the United States, the interest rate is the only variable found to be significant at the 5 percent level. In Canada, the interest rate and the value of external reserves are both found to be significant.

In Table II, the test suggested by Harvey [1981, 277] is used to test for the presence of serial correlation. The F-statistics for this test (which is based upon and asymptotically equivalent to a LaGrange Multiplier test) test that the first twelve autocorrelations are zero. The results of these tests indicate that the hypothesis of zero correlation cannot be rejected in any case.\textsuperscript{15,16}


\textsuperscript{15} The Q and Ljung-Box adjusted Q statistics are also presented in Table II. These statistics, which were used by Hoffman and Schlagenhau [1982], test that the first twelve autocorrelations in the money-growth equations are zero. For all four countries, the hypothesis cannot be rejected at the 5 percent level of significance. In addition to the tests for twelfth order autoregressive [AR(12)] errors reported in the table, tests were also performed for the presence of AR(8) and AR(4) errors. Once again, the hypothesis of white-noise residuals is not rejected in any case.

\textsuperscript{16} Another concern is that the money-growth equations may not have stable coefficients due to changes in regime over the sample period. However, as Mishkin [1983, 54–55] notes, this is equivalent to omitting relevant variables from the money-forecasting equations, which Mishkin proves does not invalidate the test statistics. The omission of variables will only result in less powerful tests. An important caveat to this statement is that the regime change does not alter the variance of the error term. However, Goldfeld-Quandt tests for homoskedasticity of the errors in the money-growth equations of the VAR model are not rejected in any of the countries.
TABLE I
F-Statistics for the Potential Monetary Policy Response Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Canada</th>
<th>Germany</th>
<th>United Kingdom</th>
<th>United States</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R$</td>
<td>5.47*</td>
<td>4.48*</td>
<td>3.30*</td>
<td>2.66*</td>
</tr>
<tr>
<td>$G$</td>
<td>0.37</td>
<td>0.40</td>
<td>1.84</td>
<td>0.27</td>
</tr>
<tr>
<td>$DEF$</td>
<td>1.54</td>
<td>0.53</td>
<td>1.47</td>
<td>0.80</td>
</tr>
<tr>
<td>$U$</td>
<td>2.32</td>
<td>0.94</td>
<td>1.90</td>
<td>1.03</td>
</tr>
<tr>
<td>$NGNP$</td>
<td>1.88</td>
<td>1.22</td>
<td>1.32</td>
<td>1.79</td>
</tr>
<tr>
<td>$Gnp$</td>
<td>1.82</td>
<td>1.56</td>
<td>0.91</td>
<td>1.12</td>
</tr>
<tr>
<td>$P$</td>
<td>1.76</td>
<td>0.16</td>
<td>1.51</td>
<td>0.10</td>
</tr>
<tr>
<td>$BPC$</td>
<td>0.32</td>
<td>1.53</td>
<td>0.64</td>
<td>2.41</td>
</tr>
<tr>
<td>$RES$</td>
<td>2.80*</td>
<td>0.43</td>
<td>0.53</td>
<td>1.05</td>
</tr>
</tbody>
</table>

Note: * denotes significance at the 5 percent level.

TABLE II
Autocorrelation Statistics for the Money Growth Equations

<table>
<thead>
<tr>
<th>Country</th>
<th>Q</th>
<th>Adjusted-Q</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>10.38</td>
<td>11.69</td>
<td>1.15</td>
</tr>
<tr>
<td>Germany</td>
<td>8.07</td>
<td>8.94</td>
<td>0.85</td>
</tr>
<tr>
<td>UK</td>
<td>7.32</td>
<td>8.35</td>
<td>0.58</td>
</tr>
<tr>
<td>US</td>
<td>11.98</td>
<td>9.26</td>
<td>1.20</td>
</tr>
</tbody>
</table>

Notes: Critical $Q_{0.05} = 21.0$
Critical $F_{0.05} = 2.04$

Results of the Tests of Rationality, Neutrality, and the MRE Hypotheses.

In this section, joint tests of rationality and neutrality, tests of rationality without imposing neutrality, and tests of neutrality with rationality as a maintained hypothesis are conducted for the four countries in the sample.

The first task is to ensure that the results obtained by Mishkin and Hoffman and Schlagenhau using expected current money growth rates can be duplicated with the sample used here. These results are presented in Table III. The only qualitative difference between the results in the table and those of Hoffman and Schlagenhau occurs for Canada in the eleven-lag case. In

---

17. Hoffman and Schlagenhau duplicate Mishkin’s results for the U.S. using their sample period 1960:I–1980:IV. The sample used here is 1963:I–1983:IV, which is the same overall length as the sample used by Hoffman and Schlagenhau, but begins and ends three years later.
the Hoffman and Schlagenhauf results, the joint, rationality, and neutrality hypotheses are all accepted for both the seven- and eleven-lag specifications. In the results for the sample used here, the neutrality and joint hypotheses are rejected in the eleven-lag case. However, this difference in the two sets of results accentuates the difference between the results obtained below using expected future changes in money growth and those obtained by previous researchers who use expected current changes in money growth. Thus, any difference in the results obtained below and those obtained by previous researchers is not due to the difference in the sample period.

**TABLE III**
Likelihood Tests of the Rationality and Neutrality Hypotheses Using Expected Current Money Growth to Explain Real Output

<table>
<thead>
<tr>
<th>Lag Length of Seven</th>
<th>Country</th>
<th>Joint Hypothesis</th>
<th>Neutrality Hypothesis</th>
<th>Rationality Hypothesis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>( x^2 ) (19)</td>
<td>( x^2 ) (8)</td>
<td>( x^2 ) (11)</td>
</tr>
<tr>
<td></td>
<td>Canada</td>
<td>27.26</td>
<td>13.59</td>
<td>3.63</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(.0988)</td>
<td>(.0931)</td>
<td>(.9796)</td>
</tr>
<tr>
<td></td>
<td>Germany</td>
<td>34.08</td>
<td>20.54</td>
<td>14.42</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(.0033)</td>
<td>(.0085)</td>
<td>(.0442)</td>
</tr>
<tr>
<td></td>
<td>UK</td>
<td>35.08</td>
<td>16.98</td>
<td>9.71</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(.0024)</td>
<td>(.0303)</td>
<td>(.2056)</td>
</tr>
<tr>
<td></td>
<td>US</td>
<td>24.07</td>
<td>13.36</td>
<td>13.16</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(.0639)</td>
<td>(.1000)</td>
<td>(.0683)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lag Length of Eleven</th>
</tr>
</thead>
<tbody>
<tr>
<td>Country</td>
</tr>
<tr>
<td>Canada</td>
</tr>
<tr>
<td>Germany</td>
</tr>
<tr>
<td>UK</td>
</tr>
<tr>
<td>US</td>
</tr>
</tbody>
</table>

Notes: The marginal significance level appears in parentheses. Also, the individual hypotheses are generated sequentially in the creation of these test statistics. That is, the null hypothesis of neutrality is tested under the maintained hypothesis of rationality, while the rationality hypothesis is tested in isolation without imposing neutrality. The estimates are corrected for degrees of freedom.

*Policy Response Variables*

<table>
<thead>
<tr>
<th>United Kingdom</th>
<th>United States</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.30*</td>
<td>2.66*</td>
</tr>
<tr>
<td>1.84</td>
<td>0.27</td>
</tr>
<tr>
<td>1.47</td>
<td>0.80</td>
</tr>
<tr>
<td>1.90</td>
<td>1.03</td>
</tr>
<tr>
<td>1.32</td>
<td>1.79</td>
</tr>
<tr>
<td>0.91</td>
<td>1.12</td>
</tr>
<tr>
<td>1.51</td>
<td>0.10</td>
</tr>
<tr>
<td>0.64</td>
<td>2.41</td>
</tr>
<tr>
<td>0.53</td>
<td>1.05</td>
</tr>
</tbody>
</table>

*Money Growth Equations*

<table>
<thead>
<tr>
<th>Adjusted-Q</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.69</td>
<td>1.15</td>
</tr>
<tr>
<td>8.94</td>
<td>0.85</td>
</tr>
<tr>
<td>8.35</td>
<td>0.58</td>
</tr>
<tr>
<td>9.26</td>
<td>1.20</td>
</tr>
</tbody>
</table>

*utility, and the MRE Hypotheses.*

and neutrality, tests of rationality utality with rationality as a main-
ur countries in the sample.
Its obtained by Mishkin and Hof-
turrent money growth rates can be tese results are presented in Table 8 the results in the table and those Canada in the eleven-lag case. In
n's results for the U.S. using their sample 1-1983:IV, which is the same overall length at begins and ends three years later.
In Tables IV and V, the constrained estimates of the output equations for each country (i.e., where rationality is maintained) are presented. An examination of these estimates reveals that the coefficients on unanticipated money growth are generally positive, significant, and follow the usual inverted-V pattern. In the few instances where negative signs do appear on unanticipated money growth, the coefficients are not significant. The coefficients on the measure of anticipated money used here tell a similar story. They are also generally positive, significant, and follow an inverted-V pattern. However, in this case, there are a few isolated instances of significant negative coefficients. The existence of these negative coefficients may be due to the imposition of the polynomial distributed lag restrictions. These restrictions will attempt to allocate the output effects over all lags, even when this is not appropriate. This can cause negative values near the tails of the polynomial when the assumed lag length is much longer than the true lag length. As evidence of this, it should be noted that most of the negative values occur near the tails of the longer, eleven-lag specifications. The negative coefficients could also be due to the dynamic pattern of output described in the theoretical section. When there is an expected future transitory increase in money growth, output first rises, then falls back to its original level. When coupled with adjustment costs, this fall in output can be used to explain the existence of negative coefficients.

In Table VI, the results of the tests of the rationality, neutrality, and MRE hypotheses are summarized. Consider first the results of the MRE hypothesis, which is composed of the joint hypotheses of rationality and neutrality. With the exception of Canada in the seven-lag case, this hypothesis is rejected for every country under both the seven- and eleven-lag specifications. These results are interesting when compared to other work in this area and the results in Table III. Hoffman and Schlagenhauf [1982] reject the MRE hypothesis when the lag length is eleven in three of the four countries considered here, with Canada being the only case where the MRE cannot be rejected. However, in the duplication of the Hoffman and Schlagenhauf results presented in Table III, the MRE hypothesis is also rejected for Canada. When the lag length is assumed to be seven by Hoffman and Schlagenhauf

18. When the estimates for the United Kingdom were examined, it was clear that the assumption of a fourth-order autoregressive process for the errors in the output equation was not sufficient to remove the autocorrelation in the model. For example, in the seven-lag case with rationality imposed (see Table IV), the Durbin-Watson statistic is 1.56. This value is in the indeterminate range, but the presence of serial correlation is further indicated by the insignificant t-statistics for the first three autoregressive parameters and a t-statistic of 9.97 for the fourth. In Table V, the same model is estimated under the assumption of AR(5) errors and all of the autocorrelations problems appear to be resolved. The Durbin-Watson statistic is 2.12 and all five of the autoregression coefficients are significant at the 5 percent level. A similar story holds for all other estimates presented for the United Kingdom. Thus, both the AR(4) and AR(5) results are included in the tables, but only the results of the AR(5) specification are discussed in the text since the results in the AR(4) case are of dubious validity.

19. The estimates of the VAR money-growth equations are available upon request.
rates of the output equations for intangible) are presented. An the coefficients on unanticipated ificant, and follow the usual indenominal negative signs do appear on its are not significant. The coe-

s used here tell a similar story. t, and follow an inverted-V pat-

isolated instances of significant se negative coefficients may be istributed lag restrictions. These effects over all lags, even whenative values near the tails of the s much longer than the true lag noted that most of the negative en-lag specifications. The nega-

monic pattern of output described expected future transitory increase is back to its original level. When output can be used to explain the 

e rationality, neutrality, and MRE he results of the MRE hypothesis, of rationality and neutrality. With use, this hypothesis is rejected for eleven-lag specifications. These other work in this area and the genhaft [1982] reject the MRE n three of the four countries con-case where the MRE cannot be the Hoffman and Schlagenauf othesis is also rejected for Canada. in by Hoffman and Schlagenauf 

e examined, it was clear that the assump-
ors in the output equation was not sufficient ple, in the seven-lag case with rationality is 1.56. This value is in the indeterminate r indicated by the insignificant t-statistics tastic of 9.97 for the fourth. In Table V, AR(5) errors and all of the autocorrelations atastic is 2.12 and all of the autoregres-

A similar story holds for all other estimates r(4) and AR(5) results are included in the s are discussed in the text since the results ations are available upon request.

<p>| TABLE IV |
|---|---|---|---|---|
| Constrained Nonlinear Output Equation Estimates: Seven Lags |</p>
<table>
<thead>
<tr>
<th></th>
<th>Canada</th>
<th>Germany</th>
<th>UK4</th>
<th>UK5</th>
<th>US</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>5.836</td>
<td>6.748</td>
<td>3.766</td>
<td>3.666</td>
<td>7.048</td>
</tr>
<tr>
<td>(1.52)</td>
<td>(1.94)</td>
<td>(0.94)</td>
<td>(0.21)</td>
<td>(1.15)</td>
<td></td>
</tr>
<tr>
<td>Trend</td>
<td>-0.0003</td>
<td>0.0035</td>
<td>0.0054</td>
<td>0.0050</td>
<td>0.0064</td>
</tr>
<tr>
<td>(0.013)</td>
<td>(0.002)</td>
<td>(0.001)</td>
<td>(0.0004)</td>
<td>(0.001)</td>
<td></td>
</tr>
<tr>
<td>β0</td>
<td>-0.0156</td>
<td>0.0644</td>
<td>0.0591</td>
<td>0.0833</td>
<td>0.2981</td>
</tr>
<tr>
<td>(0.052)</td>
<td>(0.069)</td>
<td>(1.07)</td>
<td>(0.74)</td>
<td>(0.14)</td>
<td></td>
</tr>
<tr>
<td>β1</td>
<td>0.3348</td>
<td>1.1218</td>
<td>1.9782</td>
<td>3.239</td>
<td>5.1838</td>
</tr>
<tr>
<td>(0.059)</td>
<td>(1.122)</td>
<td>(1.122)</td>
<td>(1.142)</td>
<td>(1.148)</td>
<td></td>
</tr>
<tr>
<td>β2</td>
<td>0.1698</td>
<td>0.2017</td>
<td>0.2734</td>
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<td>0.5315</td>
</tr>
<tr>
<td>(0.069)</td>
<td>(1.157)</td>
<td>(1.156)</td>
<td>(1.188)</td>
<td>(1.197)</td>
<td></td>
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<tr>
<td>β3</td>
<td>0.1909</td>
<td>0.2782</td>
<td>0.2954</td>
<td>0.4269</td>
<td>0.5466</td>
</tr>
<tr>
<td>(0.075)</td>
<td>(1.193)</td>
<td>(1.170)</td>
<td>(2.05)</td>
<td>(2.16)</td>
<td></td>
</tr>
<tr>
<td>β4</td>
<td>0.1758</td>
<td>0.3319</td>
<td>0.2727</td>
<td>0.3337</td>
<td>0.5132</td>
</tr>
<tr>
<td>(0.074)</td>
<td>(2.11)</td>
<td>(1.163)</td>
<td>(1.198)</td>
<td>(2.06)</td>
<td></td>
</tr>
<tr>
<td>β5</td>
<td>0.1325</td>
<td>0.3497</td>
<td>0.2137</td>
<td>0.1773</td>
<td>0.4442</td>
</tr>
<tr>
<td>(0.068)</td>
<td>(2.06)</td>
<td>(1.44)</td>
<td>(1.17)</td>
<td>(1.174)</td>
<td></td>
</tr>
<tr>
<td>β6</td>
<td>0.0681</td>
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<td>0.1264</td>
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<td>0.3514</td>
</tr>
<tr>
<td>(0.063)</td>
<td>(1.73)</td>
<td>(1.30)</td>
<td>(1.48)</td>
<td>(1.131)</td>
<td></td>
</tr>
<tr>
<td>β7</td>
<td>-0.0108</td>
<td>0.2568</td>
<td>0.0178</td>
<td>-0.662</td>
<td>0.2457</td>
</tr>
<tr>
<td>(0.063)</td>
<td>(1.28)</td>
<td>(1.40)</td>
<td>(0.144)</td>
<td>(0.098)</td>
<td></td>
</tr>
<tr>
<td>β8</td>
<td>-0.1716</td>
<td>-0.2986</td>
<td>-0.7382</td>
<td>-3.142</td>
<td>1.365</td>
</tr>
<tr>
<td>(0.088)</td>
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<td>(0.324)</td>
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<td>(0.376)</td>
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<tr>
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<td>1.570</td>
</tr>
<tr>
<td>(0.081)</td>
<td>(0.73)</td>
<td>(0.284)</td>
<td>(2.13)</td>
<td>(0.023)</td>
<td></td>
</tr>
<tr>
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<td>-0.0152</td>
<td>-0.1251</td>
<td>-0.4986</td>
<td>0.1982</td>
<td>1.750</td>
</tr>
<tr>
<td>(0.079)</td>
<td>(0.75)</td>
<td>(0.253)</td>
<td>(1.159)</td>
<td>(0.026)</td>
<td></td>
</tr>
<tr>
<td>β11</td>
<td>0.0463</td>
<td>0.2100</td>
<td>-0.3670</td>
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</tr>
<tr>
<td>(0.078)</td>
<td>(0.73)</td>
<td>(0.231)</td>
<td>(1.22)</td>
<td>(0.023)</td>
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</tr>
<tr>
<td>β12</td>
<td>0.0884</td>
<td>0.7842</td>
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</tr>
<tr>
<td>(0.078)</td>
<td>(0.84)</td>
<td>(0.217)</td>
<td>(1.10)</td>
<td>(0.084)</td>
<td></td>
</tr>
<tr>
<td>β13</td>
<td>0.1038</td>
<td>1.6611</td>
<td>-1.026</td>
<td>0.6525</td>
<td>2.022</td>
</tr>
<tr>
<td>(0.078)</td>
<td>(1.31)</td>
<td>(0.209)</td>
<td>(1.25)</td>
<td>(0.059)</td>
<td></td>
</tr>
<tr>
<td>β14</td>
<td>0.0849</td>
<td>2.509</td>
<td>-0.195</td>
<td>0.639</td>
<td>1.976</td>
</tr>
<tr>
<td>(0.084)</td>
<td>(2.21)</td>
<td>(0.213)</td>
<td>(1.165)</td>
<td>(0.890)</td>
<td></td>
</tr>
<tr>
<td>β15</td>
<td>0.0233</td>
<td>4.604</td>
<td>12.68</td>
<td>5.187</td>
<td>1.835</td>
</tr>
<tr>
<td>(0.110)</td>
<td>(3.56)</td>
<td>(2.46)</td>
<td>(2.34)</td>
<td>(0.946)</td>
<td></td>
</tr>
<tr>
<td>p1</td>
<td>1.160</td>
<td>0.6345</td>
<td>0.0766</td>
<td>0.3039</td>
<td>1.034</td>
</tr>
<tr>
<td>(1.75)</td>
<td>(1.42)</td>
<td>(0.82)</td>
<td>(1.31)</td>
<td>(1.23)</td>
<td></td>
</tr>
<tr>
<td>p2</td>
<td>0.1310</td>
<td>0.0541</td>
<td>-0.0504</td>
<td>-2.143</td>
<td>-1.765</td>
</tr>
<tr>
<td>(2.63)</td>
<td>(1.70)</td>
<td>(0.82)</td>
<td>(0.95)</td>
<td>(1.69)</td>
<td></td>
</tr>
<tr>
<td>p3</td>
<td>-3.334</td>
<td>2.8833</td>
<td>-0.083</td>
<td>-2.083</td>
<td>1.809</td>
</tr>
<tr>
<td>(2.65)</td>
<td>(1.74)</td>
<td>(0.84)</td>
<td>(0.92)</td>
<td>(1.59)</td>
<td></td>
</tr>
<tr>
<td>p4</td>
<td>-0.0291</td>
<td>-0.0674</td>
<td>0.8368</td>
<td>0.7160</td>
<td>0.0961</td>
</tr>
<tr>
<td>(1.82)</td>
<td>(1.47)</td>
<td>(0.84)</td>
<td>(1.094)</td>
<td>(1.115)</td>
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<tr>
<td>p5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>DW</td>
<td>2.00</td>
<td>2.17</td>
<td>1.56</td>
<td>2.12</td>
<td>1.99</td>
</tr>
</tbody>
</table>

Note: Standard errors in parentheses. Model estimated under the maintained hypothesis of rationality. The p's are the autocorrelation coefficients.
### TABLE V
Constrained Nonlinear Output Equation Estimates: Eleven Lags

<table>
<thead>
<tr>
<th></th>
<th>Canada</th>
<th>Germany</th>
<th>UK4</th>
<th>UK5</th>
<th>US</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>5.093</td>
<td>6.828</td>
<td>3.711</td>
<td>3.709</td>
<td>6.613</td>
</tr>
<tr>
<td></td>
<td>(0.033)</td>
<td>(0.062)</td>
<td>(0.026)</td>
<td>(0.024)</td>
<td>(0.365)</td>
</tr>
<tr>
<td>Trend</td>
<td>0.0882</td>
<td>0.0067</td>
<td>0.0041</td>
<td>0.0042</td>
<td>0.0067</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>β0</td>
<td>0.0225</td>
<td>-0.0226</td>
<td>0.0737</td>
<td>1.098</td>
<td>0.342</td>
</tr>
<tr>
<td></td>
<td>(0.058)</td>
<td>(0.090)</td>
<td>(0.085)</td>
<td>(0.092)</td>
<td>(0.094)</td>
</tr>
<tr>
<td>β1</td>
<td>0.1336</td>
<td>0.3116</td>
<td>0.2288</td>
<td>0.2458</td>
<td>0.3909</td>
</tr>
<tr>
<td></td>
<td>(0.061)</td>
<td>(0.134)</td>
<td>(0.085)</td>
<td>(0.085)</td>
<td>(0.204)</td>
</tr>
<tr>
<td>β2</td>
<td>0.1512</td>
<td>0.4552</td>
<td>0.3325</td>
<td>0.3399</td>
<td>0.3811</td>
</tr>
<tr>
<td></td>
<td>(0.072)</td>
<td>(0.172)</td>
<td>(0.112)</td>
<td>(0.109)</td>
<td>(0.329)</td>
</tr>
<tr>
<td>β3</td>
<td>0.1492</td>
<td>0.4578</td>
<td>0.3919</td>
<td>0.3975</td>
<td>0.3924</td>
</tr>
<tr>
<td></td>
<td>(0.080)</td>
<td>(0.179)</td>
<td>(0.136)</td>
<td>(0.131)</td>
<td>(0.415)</td>
</tr>
<tr>
<td>β4</td>
<td>0.1313</td>
<td>0.3634</td>
<td>0.4134</td>
<td>0.4238</td>
<td>0.2510</td>
</tr>
<tr>
<td></td>
<td>(0.083)</td>
<td>(0.166)</td>
<td>(0.150)</td>
<td>(0.145)</td>
<td>(0.465)</td>
</tr>
<tr>
<td>β5</td>
<td>0.1010</td>
<td>0.2107</td>
<td>0.4033</td>
<td>0.4236</td>
<td>0.1597</td>
</tr>
<tr>
<td></td>
<td>(0.082)</td>
<td>(0.147)</td>
<td>(0.155)</td>
<td>(0.150)</td>
<td>(0.483)</td>
</tr>
<tr>
<td>β6</td>
<td>0.0615</td>
<td>0.0332</td>
<td>0.3675</td>
<td>0.4017</td>
<td>0.0679</td>
</tr>
<tr>
<td></td>
<td>(0.076)</td>
<td>(0.136)</td>
<td>(0.153)</td>
<td>(0.148)</td>
<td>(0.475)</td>
</tr>
<tr>
<td>β7</td>
<td>0.0158</td>
<td>-0.1412</td>
<td>0.3113</td>
<td>0.3622</td>
<td>-0.0135</td>
</tr>
<tr>
<td></td>
<td>(0.069)</td>
<td>(0.141)</td>
<td>(0.146)</td>
<td>(0.142)</td>
<td>(0.444)</td>
</tr>
<tr>
<td>β8</td>
<td>-0.0335</td>
<td>-0.2900</td>
<td>0.2399</td>
<td>0.3092</td>
<td>-0.0751</td>
</tr>
<tr>
<td></td>
<td>(0.060)</td>
<td>(0.156)</td>
<td>(0.136)</td>
<td>(0.133)</td>
<td>(0.393)</td>
</tr>
<tr>
<td>β9</td>
<td>-0.0838</td>
<td>-0.3949</td>
<td>0.1579</td>
<td>0.2465</td>
<td>-0.1088</td>
</tr>
<tr>
<td></td>
<td>(0.054)</td>
<td>(0.170)</td>
<td>(0.128)</td>
<td>(0.126)</td>
<td>(0.325)</td>
</tr>
<tr>
<td>β10</td>
<td>-0.1330</td>
<td>-0.4448</td>
<td>0.0696</td>
<td>0.1775</td>
<td>-0.1080</td>
</tr>
<tr>
<td></td>
<td>(0.051)</td>
<td>(0.175)</td>
<td>(0.123)</td>
<td>(0.122)</td>
<td>(0.244)</td>
</tr>
<tr>
<td>β11</td>
<td>-0.1792</td>
<td>-0.4329</td>
<td>0.0209</td>
<td>0.1053</td>
<td>-0.0676</td>
</tr>
<tr>
<td></td>
<td>(0.052)</td>
<td>(0.166)</td>
<td>(0.125)</td>
<td>(0.125)</td>
<td>(0.164)</td>
</tr>
<tr>
<td>β12</td>
<td>-0.0693</td>
<td>-0.3577</td>
<td>0.3118</td>
<td>0.2063</td>
<td>1.783</td>
</tr>
<tr>
<td></td>
<td>(0.059)</td>
<td>(0.144)</td>
<td>(0.241)</td>
<td>(0.224)</td>
<td>(0.488)</td>
</tr>
<tr>
<td>β13</td>
<td>-0.0838</td>
<td>-0.2233</td>
<td>0.2348</td>
<td>-0.1526</td>
<td>4.108</td>
</tr>
<tr>
<td></td>
<td>(0.055)</td>
<td>(0.111)</td>
<td>(0.237)</td>
<td>(0.220)</td>
<td>(2.651)</td>
</tr>
<tr>
<td>β14</td>
<td>0.0549</td>
<td>-0.0900</td>
<td>-0.1456</td>
<td>-0.0891</td>
<td>4.379</td>
</tr>
<tr>
<td></td>
<td>(0.054)</td>
<td>(0.081)</td>
<td>(0.229)</td>
<td>(0.214)</td>
<td>(2.783)</td>
</tr>
<tr>
<td>β15</td>
<td>0.1182</td>
<td>0.1804</td>
<td>-0.0496</td>
<td>-0.0175</td>
<td>4.577</td>
</tr>
<tr>
<td></td>
<td>(0.057)</td>
<td>(0.084)</td>
<td>(0.219)</td>
<td>(0.207)</td>
<td>(2.867)</td>
</tr>
<tr>
<td>β16</td>
<td>0.1793</td>
<td>0.4148</td>
<td>0.0538</td>
<td>0.0606</td>
<td>4.680</td>
</tr>
<tr>
<td></td>
<td>(0.062)</td>
<td>(0.225)</td>
<td>(0.206)</td>
<td>(0.198)</td>
<td>(2.888)</td>
</tr>
<tr>
<td>β17</td>
<td>0.2356</td>
<td>0.6389</td>
<td>0.1608</td>
<td>0.1430</td>
<td>4.670</td>
</tr>
<tr>
<td></td>
<td>(0.067)</td>
<td>(0.180)</td>
<td>(0.190)</td>
<td>(0.186)</td>
<td>(2.844)</td>
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<tr>
<td>β18</td>
<td>0.2843</td>
<td>0.8220</td>
<td>0.2679</td>
<td>0.2274</td>
<td>4.522</td>
</tr>
<tr>
<td></td>
<td>(0.071)</td>
<td>(0.225)</td>
<td>(0.170)</td>
<td>(0.172)</td>
<td>(2.727)</td>
</tr>
<tr>
<td>β19</td>
<td>0.3223</td>
<td>0.9278</td>
<td>0.3116</td>
<td>0.3113</td>
<td>4.214</td>
</tr>
<tr>
<td></td>
<td>(0.072)</td>
<td>(0.248)</td>
<td>(0.149)</td>
<td>(0.157)</td>
<td>(2.520)</td>
</tr>
<tr>
<td>β20</td>
<td>0.3464</td>
<td>0.9150</td>
<td>0.4678</td>
<td>0.3917</td>
<td>3.720</td>
</tr>
<tr>
<td></td>
<td>(0.073)</td>
<td>(0.238)</td>
<td>(0.136)</td>
<td>(0.146)</td>
<td>(2.231)</td>
</tr>
<tr>
<td>β21</td>
<td>0.3528</td>
<td>0.7367</td>
<td>0.5521</td>
<td>0.4654</td>
<td>3.014</td>
</tr>
<tr>
<td></td>
<td>(0.074)</td>
<td>(0.186)</td>
<td>(0.145)</td>
<td>(0.151)</td>
<td>(1.861)</td>
</tr>
</tbody>
</table>
\[\begin{array}{cccccc}
\hline
\text{Lags} & \text{UK4} & \text{UK5} & \text{US} \\
\hline
11 & 3.709 & 6.613 \\
26 & (.024) & (.365) \\
041 & .0042 & .0067 \\
011 & (.001) & (.001) \\
737 & .1098 & .3421 \\
85 & (.092) & (.094) \\
288 & .2458 & .3909 \\
85 & (.085) & (.204) \\
325 & .3399 & .3811 \\
12 & (.109) & (.329) \\
919 & .3975 & .3294 \\
36 & (.131) & (.415) \\
134 & .4238 & .2510 \\
50 & (.145) & (.465) \\
033 & .4236 & .1597 \\
55 & (.150) & (.483) \\
675 & .4017 & .0679 \\
53 & (.148) & (.475) \\
113 & .3622 & .0135 \\
46 & (.142) & (.444) \\
399 & .3092 & .0751 \\
36 & (.133) & (.393) \\
579 & .2465 & .1088 \\
28 & (.126) & (.325) \\
696 & .1775 & .1080 \\
23 & (.122) & (.244) \\
209 & .1053 & .0676 \\
25 & (.125) & (.164) \\
118 & .2065 & 3.780 \\
41 & (.224) & (2.48) \\
348 & (.1526) & 4.108 \\
37 & (.220) & (2.65) \\
466 & .0891 & 4.379 \\
29 & (.214) & (2.78) \\
496 & .0175 & 4.577 \\
19 & (.207) & (2.86) \\
538 & 0.0606 & 4.680 \\
06 & (.198) & (2.88) \\
608 & .1430 & 4.670 \\
90 & (.186) & (2.84) \\
679 & .2274 & 4.522 \\
70 & (.172) & (2.72) \\
716 & .3113 & 4.214 \\
49 & (.157) & (2.52) \\
678 & .3917 & 3.720 \\
36 & (.146) & (2.23) \\
521 & .4654 & 3.014 \\
45 & (.151) & (1.86) \\
\hline
\end{array}\]

Note: Standard errors in parentheses. Model estimated under the maintained hypothesis of rationality. The \(p\)'s are the autocorrelation coefficients.

[1982], they fail to reject the hypothesis for two of the four countries in the sample, Canada and the United States. Identical results were obtained in Table III for the seven-lag case. Mishkin [1983] also fails to reject the joint hypothesis for the United States when a lag length of seven is assumed. Thus, Mishkin [1983], Hoffman and Schlagenhaft [1982], and the results of Table III clearly reject the MRE in the longer-lag specifications.

As discussed above, both Mishkin [1983] and Hoffman and Schlagenhaft [1982] justify the use of the longer lag lengths, eleven for Hoffman and Schlagenhaft [1982] and twenty for Mishkin [1982; 1983], based upon the work of Leamer [1978]. They claim that failure to reject the hypothesis when the lag length is assumed to be seven must be due to misspecification of the lag length, and that therefore the longer lag lengths are appropriate. However, the results obtained here indicate that changing the specification of the output equation to contain expected future rather than expected current changes in the money growth rate helps to remove this inconsistency across lag lengths. This is further indicated by the individual tests of rationality and neutrality.

Consider the results of the rationality hypothesis next. An examination of the results reveals that rationality is not rejected in any country for either lag length. Thus, these results are highly supportive of the change in the specification of the expected money-growth terms used in this paper, especially when compared to previous work and the results of Table III. Hoffman
TABLE VI
Likelihood Tests of the Rationality and Neutrality Hypotheses Using Expected Future Money Growth to Explain Real Output

<table>
<thead>
<tr>
<th>Country</th>
<th>Joint Hypothesis</th>
<th>Neutrality Hypothesis</th>
<th>Rationality Hypothesis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( x^2 ) (19) = 20.46 (0.0001)</td>
<td>( x^2 ) (8) = 15.34 (0.0001)</td>
<td>( x^2 ) (11) = 6.702 (0.0001)</td>
</tr>
<tr>
<td>Canada</td>
<td>( x^2 ) (15) = 31.32 (0.0001)</td>
<td>( x^2 ) (8) = 16.38 (0.0001)</td>
<td>( x^2 ) (7) = 7.142 (0.0001)</td>
</tr>
<tr>
<td>Germany</td>
<td>( x^2 ) (15) = 21.53 (0.0001)</td>
<td>( x^2 ) (8) = 5.313 (0.0001)</td>
<td>( x^2 ) (7) = 13.25 (0.0001)</td>
</tr>
<tr>
<td>UK-AR(4)</td>
<td>( x^2 ) (15) = 44.89 (0.0001)</td>
<td>( x^2 ) (8) = 31.52 (0.0001)</td>
<td>( x^2 ) (7) = 5.165 (0.0001)</td>
</tr>
<tr>
<td>UK-AR(5)</td>
<td>( x^2 ) (15) = 39.03 (0.0001)</td>
<td>( x^2 ) (8) = 33.16 (0.0001)</td>
<td>( x^2 ) (7) = 5.165 (0.0001)</td>
</tr>
<tr>
<td>US</td>
<td>( x^2 ) (19) = 31.26 (0.0001)</td>
<td>( x^2 ) (8) = 26.09 (0.0001)</td>
<td>( x^2 ) (7) = 6.081 (0.0001)</td>
</tr>
</tbody>
</table>

Notes: The marginal significance level appears in parentheses. Also, the individual hypotheses are generated sequentially in the creation of these test statistics. That is, the null hypothesis of neutrality is tested under the maintained hypothesis of rationality, while the rationality hypothesis is tested in isolation without imposing neutrality. The estimates are corrected for degrees of freedom.

and Schlagenhau [1982] reject the rationality of expectations only for Germany when a lag length of seven is assumed. However, when the lag length is extended to eleven, the rationality of expectations is also rejected for the United States. Thus, in their preferred specification of eleven lags, rationality is rejected for two of the four countries considered in this investigation. Identical results for the seven- and eleven-lag cases are obtained in Table
III. Mishkin [1983] finds the same result for the United States. Rationality is not rejected for a lag length of seven, but when a lag length of twenty is assumed, Mishkin's preferred specification, rationality of expectations, is rejected.

The results of the tests of neutrality with rationality taken as a maintained hypothesis are also supportive of the specification adopted in this paper. In the eleven-lag case, the neutrality of anticipated monetary policy is rejected in all countries. Hoffman and Schlagenhauf [1982] reject neutrality in their eleven-lag specification in all countries except for Canada. However, in Table III, neutrality is also rejected for Canada.

In the seven-lag specification, neutrality is rejected for all countries except for Canada. However, the hypothesis is nearly rejected in this case as well. The significance level of 0.05 is very close to the 0.05 level required for rejection; but, nevertheless, this must be considered a failure to reject the null hypothesis given the a priori level of significance. Hoffman and Schlagenhauf [1982] fail to reject the neutrality hypothesis for both Canada and the United States in the seven-lag case, a result duplicated in Table III. Therefore, across lag lengths, neutrality is accepted in three of eight cases (i.e., twice under the seven-lag specification and once under the eleven-lag specification) by Hoffman and Schlagenhauf [1982], and twice in Table III. In the same eight cases considered here, neutrality is only weakly accepted in one case (i.e., once in the seven-lag case).

Overall the results are very favorable. Rationality is accepted in all cases and failure to reject neutrality occurs in only Canada for the seven-lag specification. This seems to indicate strong support for using expected future changes in the money growth rate in the empirical output equation.

V. CONCLUSIONS

This paper has examined the real effects of anticipated and unanticipated changes in the money growth rate. First, theoretical models were examined in which anticipated transitory changes in the money growth rate are non-neutral. The real effects arise from the expectation of a change in the money growth and inflation rates in some future time period. If there is no expectation of a change in money growth and inflation in the future, as in the case of an unanticipated transitory change in money growth, then no real effects are realized in these models.

Based upon the theoretical results, an econometric model was developed in which the explanatory variable in the output equation is expected future changes in money growth, rather than expected current changes as in previous work. Tests of the rationality, neutrality, and MRE hypotheses revealed that the rationality of expectations and the nonneutrality of money were strongly supported by the data; and, unlike previous work, the results were robust to changes in the lag specification of the empirical output equation.
This robustness is encouraging because it appears to lend credence to the use of expected future changes in money growth rather than expected current changes.

The results of this investigation suggest that anticipated future money growth and inflation rates influence current output in ways that expected current inflation rates may not, a finding not unlike that discussed in a different context by Litterman and Weiss [1985]. In light of the fact that most empirical work on the nonneutrality of money has examined the statistical link between expected current inflation or money growth and the current value of real output, and the fact that rationality has not been strongly supported in previous empirical work, these results are important. They indicate that investigations into the nonneutrality issue should carefully consider the relationship between expected future policy events and the current value of real economic variables.

REFERENCES


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appears to lend credence to the
that anticipated future money
output in ways that expected
st unlike that discussed in a dif-
5. In light of the fact that most
has examined the statistical
money growth and the current
sity has not been strongly sup-
ents are important. They indicate
ue should carefully consider the
ents and the current value of

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