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MONETARY INFORMATION AND INTEREST RATES

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ABSTRACT

A model of interest rate movements in response to new information on the money stock is developed. The model, which incorporates several earlier approaches as special cases, makes explicit the manner in which estimated interest rate responses to money surprises depend on the relative variances of nominal and real disturbances, as well as on the monetary authority's policy and the credibility of that policy.

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MONETARY INFORMATION AND INTEREST RATES

I. Introduction

Recent empirical evidence leaves little doubt that anticipated real rates of return on a wide variety of assets are affected by the Federal Reserve's weekly release of its latest estimates of the money supply.[1] The positive co-movements of nominal interest rates and the value of the dollar, together with the negative co-movements of nominal interest rates and both commodity and stock prices are inconsistent with the hypothesis that the responses are solely due to variations in the expected rate of inflation.[2] Lagging behind the accumulation of empirical evidence has been the development of theoretical models which are capable of explicitly modelling the determinants of the response coefficients measured in the empirical work. The need for such explicit models is particularly important given the apparent shifts in parameters which the empirical work has found to coincide with changes in Federal Reserve policy.[3]

While several heuristic explanations for the asset price responses to money announcements have been offered (Cornell (1983) provides a survey), all the existing models in this area have tended to treat only a subset of the competing hypotheses. For example, Urich (1983), Walsh (1983), Nichols, Small, and Webster (1983), Roley and Walsh (1983), and Campbell (1984) construct models of weekly interest rate determination under the assumption that the aggregate price level is fixed. These models have focused on the interest rate responses as real rate responses to changes in expected future money demand relative to expected future money supply.

Roley and Walsh (1983) also construct a flexible price model in which all observed interest rate movements are due to revisions in expected inflation. Loeys (1983) incorporates sluggish price adjustment by assuming prices are fixed for a constant number of periods and completely flexible thereafter. Engle and Frankel (1984) and Hardouvelis (1985) also model the sluggish adjustment of the aggregate price level in models of the joint response of interest rates and exchange rates to money surprises. However, they assume the equilibrium price level is determined by purchasing power parity and that uncovered interest parity holds. By further taking the foreign price level and nominal interest rate to be constant, the relevance of their models to an understanding of the short-run response of U.S. interest rates to weekly announcements of the U.S. money stock may be questioned. In addition, neither of these two models explicitly characterizes the behavior of the Federal Reserve, a factor emphasized in most of the literature in this area.

Engle and Frankel (1984) and Hardouvelis (1985) also assume the long-run equilibrium real rate of interest is constant. Any movements of distant future rates must therefore, by definition, be due to changes in expected inflation, and they cannot analyze the real activity hypothesis as modelled by Siegel (1985). Under this hypothesis, a money announcement provides information on real shocks to the economy which produce changes in the long-run equilibrium real rate of interest.

The present paper develops a specific model of the interest rate response to the new information contained in the weekly money announcement. The extent to which interest rates adjust to new information on the money stock is shown to depend on the monetary authority's policy behavior, as well as the credibility of its policy, the properties characterizing the behavior of the aggregate price level, and the variance of nominal disturbances relative to real disturbances.

II. The Model

Since an interest rate such as the federal funds rate with only a one day maturity responds to money announcements,[4] it is useful to base a model of the announcement effect on a model of the market for bank reserves. Suppose that the demand for reserves by banks arises from the existence of a binding reserve requirement on deposits. Under lagged reserve accounting, as was in effect over the sample period used in most of the empirical studies cited earlier, $rr_t = k + m_{t-2}$, where rr_t is the log of required reserves during week t and m_{t-2} is the log of the money supply during week t-2.[5]

The supply of reserves consists of nonborrowed reserves (NBR_t) plus borrowed reserves (BR_t). Equilibrium in the market for reserves requires banks to be satisfied with the composition of total reserves between borrowed and nonborrowed reserves. This composition is determined by the Federal Reserve. Given the manner in which discount window borrowing is administered,[6] bank borrowing will depend on both the current federal funds rate, i_t, and the expected future value of this short-term interest rate.[7] A rise in current borrowing by an individual bank increases the implicit cost of future borrowing. Thus, if the interest rate is expected to be high next period, so that the profitability of borrowing at the discount window is expected to be high, individual banks may reduce current borrowing in order to increase access to the window next period. The desired reserve composition is assumed to be given by equation (1):

$$nbr_t - rr_t = \beta_0 - \beta_1 i_t + \beta_2 {}_t i_{t+1} + v_t \tag{1}$$

where nbr = ln(NBR) and ${}_t i_{t+1}$ is the expectation, conditional on time t information, of i_{t+1}.[8] The disturbance term v_t is assumed to be serially uncorrelated with mean zero.

Using (1),

$$i_t = \beta_1^{-1}[rr_t - nbr_t + \beta_0 + \beta_2 {}_t i_{t+1} + v_t]. \tag{2}$$

Equation (2) holds under either lagged or contemporaneous reserve accounting. Prior to a money announcement, market participants know $i_t - \beta_1^{-1}[\beta_0+\beta_2 {}_t i_{t+1}] = \beta_1^{-1}[rr_t - nbr_t + v_t]$. The weekly announcement may lead to revisions in forecasts about rr_t, nbr_t, or v_t (under lagged reserve accounting, aggregate required reserves, $rr_t = k + m_{t-2}$, become known exactly), but, given ${}_t i_{t+1}$, i_t is unaffected by these revisions as it depends, from (2), only on the linear combination $rr_t - nbr_t + v_t$ which was already known.[9]

Let Δz denote the revision in a variable z that results from the announcement in week t of m_{t-2}. Under a federal funds operating procedure, the monetary authority keeps i_t fixed during the settlement week, and nbr_t adjusts so that $\Delta i_t = 0$. Under a nonborrowed reserves operating procedure, nbr_t is kept fixed and, from (2),

$$\Delta i_t = \beta_1^{-1}\beta_2 \Delta_t i_{t+1}. \qquad (3)$$

Thus, the current short rate responds if and only if the announcement leads to a revision in expectations of the future short rate. To determine $\Delta_t i_{t+1}$, the remainder of the model must be specified.

The demand for real money balances is taken to be a decreasing function of the nominal rate of interest and an increasing function of real permanent income:[10]

$$m_t - p_t = \alpha_0 - \alpha i_t + y_t^p + u_t \qquad (4)$$

where p_t is the log of the price level and y_t^p is real permanent income. The assumptions made concerning the disturbance term u_t are very important, particularly since evidence presented in Roley and Walsh (1984) of a positive contemporaneous correlation between money and interest rates using weekly data suggests that demand shifts, as opposed to supply shifts, play a major role in observed short-run interest rate and money stock movements.[11] To capture the notion that money demand shocks have both permanent and transitory components, it is assumed that

$$u_t = u_{t-1} + \varepsilon_t - \gamma\varepsilon_{t-1}, \qquad (5)$$

where ε is a white noise disturbance term with variance σ_ε^2. The permanent component of any shock ε_t is equal to $(1-\gamma)\varepsilon_t$, while $\gamma\varepsilon_t$ represents the transitory component.[12]

Assuming permanent income is equal to the rational expectation of the present discounted value of future income suggests that y_t^p should be modelled as a random walk:

$$y_t^p = y_{t-1}^p + \psi_t. \tag{6}$$

where ψ is a serially uncorrelated mean zero random variable.

From (4), $i_{t+i} = \alpha^{-1}[\alpha_0 - m_{t+i} + p_{t+i} + y_{t+i}^p + u_{t+i}]$. Taking expectations,

$$_t i_{t+i} = \alpha^{-1}[\alpha_0 - {}_t m_{t+i} + {}_t p_{t+i} + {}_t y_{t+i}^p + {}_t u_{t+i}]. \tag{7}$$

In response to a money announcement, (7) implies

$$\Delta_t i_{t+i} = -\alpha^{-1}[\Delta_t m_{t+i} - \Delta_t p_{t+i} - \Delta_t y_{t+i}^p - \Delta_t u_{t+i}]. \tag{8}$$

Finally, if $_t r_{t+i}$ is the anticipated real rate of interest from t+i to t+i+1,

$$\Delta_t r_{t+i} = -\alpha^{-1}\Delta_t m_{t+i} - \Delta_t p_{t+i+1} + (1+\alpha^{-1})\Delta_t p_{t+i} + \alpha^{-1}\Delta_t y_{t+i}^p + \alpha^{-1}\Delta_t u_{t+i} \quad (9$$

Equation (9) is useful in illustrating the various factors different authors have emphasized in explaining the effect of announcements on interest rates. For example, Siegel (1985) can be viewed as focusing on the real income shocks affecting the equilibrium real rate of interest through the term $\Delta_t y_{t+i}^p$. If a money surprise is positively correlated with future real income, interest rates will rise if an unexpectedly large value of m_{t-2} is announced. Other models have assumed this term to be identically zero, in which case, the interest rate response depends on how new information affects expectations of the future nominal money supply, future prices, and future disturbances to money demand.

In fixed price models,[13] (9) simplifies to $\Delta_t r_{t+i} = -\alpha^{-1}[\Delta_t m_{t+i} - \Delta_t u_{t+i}]$. These models have thus emphasized the persistence of money demand disturbances and the monetary authority's policy rule governing the evolution of the nominal money stock.

To complete the specification of a general model of all the factors appearing in (9), two additional components are required: a model of aggregate demand and supply to determine the equilibrium price level and a model of the perceived behavior of the monetary authority.

Rather than explicitly model aggregate demand and supply in the goods market, a shortcut will be taken. A variety of rational expectations models of an aggregate economy imply equilibria in which the price level depends on past and current expected values of both the current and future money stock. Since equal changes in m_{t+i} and u_{t+i}, or m_{t+i} and y^p_{t+i}, have no effect on the equilibrium price level,[14] it is assumed that

$$p_t = p_{0t} + \Sigma_{s=0}^{N} d_s \Sigma_{j=0}^{\infty} b_j [{}_{t-s}m_{t+j} - {}_{t-s}u_{t+j} - {}_{t-s}y^p_{t+j}] + \phi_t. \qquad (10)$$

For example, N might be the length of the longest nominal wage contract. The current price level depends on expectations of p_t formed at times t-1 to t-N since such expectations are imbedded in the current structure of nominal wages. If p_t is expected to depend on m_t and future values of the money stock, an equation such as (10) would result. The time varying term p_{0t} will be discussed below, while ϕ_t is a white noise disturbance.

Rational expectations models which exhibit both static and dynamic neutrality impose restrictions on the d_s and b_j coefficients. First, the neutrality of money implies that proportional changes in the nominal money supply at all dates raise the price level by the same proportion. Equation (10) possess this property if and only if

$$\Sigma_0^N d_s \Sigma_0^\infty b_j = 1. \tag{11}$$

Condition (11) is not sufficient to ensure dynamic, or super, neutrality. If anticipated future real rates of interest are invariant to the anticipated path of money, further restrictions are imposed. For example, equation (10) implies that p_t is not perfectly flexible since it is partially determined by past expectations. However, the past matters for only N periods so that, from the point of view of period t, p_{t+i} for i > N is completely flexible. Hence, ${}_tr_{t+i}$ for i > N should be invarient to the anticipated (as of time t) behavior of the nominal money stock. From equation (4), this requires that, for i > N, the solution for p_t given by (10) be consistent with

$${}_tm_{t+i} - {}_tp_{t+i} = \alpha_0 - \alpha[{}_tr_{t+i}' + {}_tp_{t+i+1} - {}_tp_{t+i}] + {}_ty^p_{t+i} + {}_tu_{t+i} \tag{12}$$

where r_t' is the equilibrium real rate of interest. For simplicity, it will be assumed that r' is influenced by the same factors which affect permanent income, as well as by a transitory disturbance:

$$r'_{t+i} = r'_{t+i-1} + \delta\psi_{t+i} + v_{t+i} - v_{t+i-1}.$$

The transitory shock, v_t, captures factors other than permanent income which influence r'.[15] Equation (12) requires that the b_j's in (10) satisfy

$$b_j = \alpha^j/(1+\alpha)^{j+1},\ j = 0,\ldots \tag{13}$$

Since (13) implies $\Sigma_0^\infty b_j = 1$, (11) now requires that

$$\Sigma_{s=0}^{N} d_s = 1. \tag{14}$$

Finally, (12) and (13) imply that $p_{0t} = \alpha_0 - \Sigma[\alpha/(1+\alpha)]^{j+1}\ {}_t r'_{t+j}$. The presence of this term captures the effects of shifts in the equilibrium real interest rate on the price level.

In order to represent, in the simpliest possible way, market participants' expectations about monetary policy, the following assumptions will be made. First, it is assumed that the monetary authority follows a monetary aggregates policy in which it tries to achieve a targeted path for the money stock. Let ${}_t m^T_{t+i}$ denote the targeted value, as of time t, for m_{t+i}. Second, while the particular control techniques used to achieve the target path depend on whether a federal funds or a reserve aggregate operating procedure is being used, it is assumed that the monetary authority is expected to achieve its target. Under this assumption, ${}_t m_{t+i} = {}_t m^T_{t+i}$. Third, it is assumed that the monetary authority is expected to revise its target path for future money in light of past deviations from target. To maintain a simple structure, it will be assumed that ${}_t m^T_{t+i}$ is adjusted in response to the new information obtained in week t by the release of the data on m_{t-2}.

Two hypotheses about the monetary authority's behavior have figured prominantly in the analysis of interest rates and money announcements. The first is that the monetary authority acts to offset any deviation of money from the target path without changing the long-run growth target. This hypothesis can be represented by assuming

$$\Delta_t m^T_{t+i} = (1-\lambda)^i (m_{t-2} - m^*_{t-2}) \qquad (15)$$

where "*" will be used to denote an expectation just prior to the week t announcement of the actual value of m_{t-2}. The difference $m_{t-2} - m^*_{t-2} = \eta_{t-2}$ represents the new information contained in the announcement. According to (15), the monetary authority is expected to offset deviations from target at the rate λ per week. As $i \to \infty$, $\Delta_t m^T_{t+i} = \Delta_t m_{t+i} \dashrightarrow 0$, so that no revision of the long-run target path is anticipated.

The second hypothesis often made concerning the monetary authority's behavior is that a deviation from the old target path as revealed by the announcement of m_{t-2} is an indication that a change in the target growth rate has occured. This case can be represented by assuming

$$\Delta_t m^T_{t+i} = (i+2)\pi\eta_{t-2}, \qquad (16)$$

where π is a parameter measuring the fraction of the money surprise that gets incorporated into the new target growth rate.

During the sample period used in the empirical work on money surprises, the stated goals of the Federal Reserve were expressed in terms of ranges for the growth rates of various monetary aggregates. Since these ranges are changed only every six months, the stated policy of the Federal Reserve on a week to week basis is more closely represented by (15) than by (16).[16] However, a plausible approximation to the public's expectations of Fed behavior would place some positive probability on both possible adjustment responses to perceived deviations from target. For example, suppose it is expected with probability q that the monetary target path will be adjusted according to (15) in which deviations are gradually offset. With probability 1-q, however, the growth path is believed to be adjusted according to (16). In this case,

$$\Delta_t m_{t+i} = [q(1-\lambda)^i + (1-q)(i+2)\pi]\eta_{t-2}. \tag{17}$$

The weight q is then a simple measure of what might be described as policy credibility. A high q implies market participants expect the monetary authority to be unlikely to revise the underlying target growth rate of the money stock. Alternatively, q could be interpreted as a means of reflecting uncertainty about the monetary authority's policy.

The monetary authority can attempt to achieve its target path for the money stock by using either the funds rate or nonborrowed reserves as an operating instrument. If the funds rate is used, equation (7) defines the required path of i_{t+i}. If a nonborrowed reserves operating procedure is used, equation (2) defines the path for nbr which is consistent with the path for the funds rate required by (7) and the target path for the money stock. It is the monetary authority's operating procedure which provides an important link between the reserve market and the money market.

III. The Informational Content of Money Announcements

The weekly announcement by the Federal Reserve provides the market with the value of m_{t-2}.[17] Since r_{t-2} was observed during week t-2, and it will be assumed that individuals know the past level of prices,[18] equations (4) - (6) imply[19]

$$\eta_{t-2} = (\psi_{t-2} - \psi^*_{t-2}) + (\varepsilon_{t-2} - \varepsilon^*_{t-2}) - \gamma(\varepsilon_{t-3} - \varepsilon^*_{t-3}). \tag{18}$$

The new information contained in the announcement of η_{t-2} allows only a particular linear combination of the underlying disturbances, ψ_{t-2}, ε_{t-2}, and ε_{t-3}, to be observed. The revisions in the market's estimates of the basic shocks can be written as

$$\Delta_t \psi_{t-2} = a_{1t} \eta_{t-2} \tag{19}$$

$$\Delta_t \varepsilon_{t-2} = a_{2t} \eta_{t-2} \tag{20}$$

$$\Delta_t \varepsilon_{t-3} = a_{3t} \eta_{t-2}. \tag{21}$$

where the a_{it} are time varying Kalman filter coefficients[28] with $a_{1t} > 0$, $a_{2t} > 0$, and $a_{3t} < 0$. From (18), $a_{1t} + a_{2t} - \gamma a_{3t} = 1$.

While the announcement of m_{t-2} does reveal information on the week t-2 money demand shock, it does not allow market participants to learn ε_{t-2} exactly since η_{t-2} is also affected by real shocks to permanent income. Either unpredicted positive shocks to real income or to money demand cause m_{t-2} to be larger than anticipated. Because the observation of η_{t-2} is not sufficient to identify the underlying disturbances, any nonzero money surprise is attributed partially to each of its possible causes.

IV. Interest Rate Responses

Equations (8) and (9) can be used to calculate the responses of both anticipated future nominal and real interest rates to the money announcement. Details of the derivations are relegated to the appendix.

First, consider the change in the real rate of interest expected to prevail at time t+i with $i \geq N$:

$$\Delta_t r_{t+i} = \delta a_{1t} \eta_{t-2}, \quad i \geq N. \tag{22}$$

where δ is the covariance between permanent income and real interest rate innovations. Since all contracts in force at time t will have expired by t+N, the expected real rate for t+i is independent of any of the monetary factors such as λ, π, or the weight q determining expectations of the future money stock. Real rates do respond to real shocks, and a positive money surprise would lead to an upward revision in the real rate of interest expected in the distant future if $\delta > 0$. Such is the case if real aggregate demand shocks dominate so that real income and real interest rates are positively correlated.

For $i < N$,

$$\begin{aligned}\Delta_t r_{t+i} = \{&\delta a_{1t} + \alpha^{-1}(1-d(i))[a_{1t} + (1-\gamma)a_{2t} - \gamma a_{3t}] \\ &- \alpha^{-1}(1-d(i))[q(1-\lambda)^{i} + (1-q)\pi(i+2)] \\ &+ d_{i+1}[(i+3)(1-q)\pi - q(1-\lambda)^{i+1}/(1+\alpha\lambda)]\}\eta_{t-2}, \end{aligned} \tag{23}$$

where $d(i) = \Sigma_0^i d_j$. From (18), $d(i) = 1$ for all $i \geq N$. Comparing (22) and (23), three additional terms appear when $i < N$, and all three are functions of the price adjustment parameters. As long as prices are not perfectly flexible, real interest rates will be affected by monetary disturbances and the monetary authority's response to those disturbances.

The second term multiplying η_{t-2} in (23) is positive and captures the effect of revisions in expectations of future money demand. This term is positive since higher money demand will, ceteris paribus, increase real interest rates until prices have completely adjusted. From the definition of the a_{it}'s, $a_{1t} + (1-\gamma)a_{2t} - \gamma a_{3t} = 1 - \gamma a_{2t}$. Thus, the greater the revision in the public's estimate of ε_{t-2}, the smaller will be this term. Since η_{t-2} arises from permanent income and money demand shocks, the greater the proportion of η_{t-2} attributed to ε_{t-2} the less permanent is the shift in money demand since ψ shocks are completely permanent while ε shocks are only partially so. This term capturing expectations about future money demand has been the main focus of emphasis under the policy anticipations hypothesis. This hypothesis also emphasizes the policy response of the money supply which is represented in the third and fourth terms multipying η in (23).

The third term in (23) is negative and results from the change in expectations about the future money supply. With $\lambda < 1$, a positive money surprise implies that the money stock will remain above the old target growth path for several periods, while if $(1-q)\pi > 0$, the nominal money stock is expected to permanently remain above the old target path. This upward revision in the expected future money stock lowers, for a given money demand shock, expected real interest rates as long as prices are not able to respond completely. Combining this and the previous term shows how the real interest rate response depends on a comparison of the revisions in expectations of future money demand and supply.

The last term in (23) enters because the real rate of interest depends on the expected rate of inflation as long as $d_{i+1} \neq 0$. This final term can have either sign and depends on whether the money supply is expected to grow at a different rate than previously ($(1-q)\pi \neq 0$) or is expected to return to its old growth path. In the latter case, in which the $q(1-\lambda)^{i+1}/(1+\alpha\lambda)$ term dominates, the net effect is negative.

Earlier discussions of the money announcement effect have all emphasized some sort of active policy response as central to the response of interest rates to money surprises. Either the policy authority was assumed to revise its target growth path so that expectations of inflation rose, or the monetary authority was assumed to restrict money growth temporarily in order to return to the target growth path. As (23) makes clear, anticipated future real interest rates are affected by a money surprise even if $\lambda = \pi = 0$. <u>Even if the monetary authority allows for what is akin to base drift with no revision in the targeted growth rate, real interest rates will be affected.</u> Because the higher money demand revealed by a positive money surprise is expected to be at least partially temporary, while with base drift the rise in the nominal money supply is permanent, real rates will be lower until prices have adjusted.[21] Unless the δa_{1t} term dominates, however, some sort of policy response is necessary to explain what appears to be the positive response of real rates to positive money surprises.

Differentiating the coefficient on η_{t-2} in (23) with respect to λ shows that the response of expected real rates is increasing in λ: <u>a policy shift designed to return the money stock more quickly to the tar-</u>

get path will increase the sensitivity of real rates to money surprises if interest rates initially responded positively to such surprises. Since the shift in policy operating procedures by the Federal Reserve in October, 1979 was generally perceived as a move to keep monetary aggregates closer to the long run growth target, it could be described as a rise in λ. This would then be one possible factor in explaining the rise in the response of interest rates to money surprises that occurred after October, 1979.[22]

The observed response of nominal forward rates is the sum of the change in the relevant expected future real rate and expected future inflation. When $i \geq N$, $\Delta_t i_{t+i}$ is given by

$$\Delta_t i_{t+i} = [\delta a_{1t} - q(1-\lambda)^i \lambda/(1+\alpha\lambda) + (1-q)\pi]\eta_{t-2}, \quad i \geq N, \tag{24}$$

which converges to $[\delta a_1 + (1-q)\pi]\eta_{t-2}$ as $i \to \infty$. Hence, that some weight be given to the possibility of a revision in the target path (i.e., $q \leq 1$) is not a necessary requirement for expectations of nominal interest rates several years in the future to move in response to a money surprise. If the surprise contains any information useful in predicting changes in the equilibrium real rate of interest, $\Delta_t i_{t+i}$ will be nonzero even if no change in the target growth rate of the money stock is anticipated.

When $i < N$,

$$\begin{aligned}\Delta_t i_{t+i} = \{&\delta a_{1t} + \alpha^{-1}(1 - d(i))[1 - \gamma a_{2t}] \\ &- \alpha^{-1} q(1-\lambda)^i [1 - d(i)/(1+\alpha\lambda)] \\ &+ (1-q)\pi[d(i) - \alpha^{-1}(i+2)(1-d(i))]\}\eta_{t-2}.\end{aligned} \tag{25}$$

Because λ has opposing effects on expected inflation and expected real rates, the net effect of a change in λ on the sensitivity of nominal rates to money surprises is ambiguous. A higher λ implies a faster return to the target path, and this reduces the impact of η on future inflation. However, it increases the impact on expected real rates. For i such that d(i) is small, that is, for small i or if prices are very sluggish to adjust, the effect on real interest rates dominates, and a rise in λ will increase the response of $\Delta_t i_{t+i}$ to a money surprise.

Referring back to equation (24), a rise in λ can lead to a greater response of expected future interest rates to money surprises even for $i \geq N$ as long as $2\lambda + \alpha\lambda^2 > 1$. Thus, the increase in long-term interest rate responses to money surprises which occurred after the October 1979 shift in operating procedures is potentially consistent with market participants believing the Federal Reserve would move more quickly to eliminate deviations from the targeted growth path. Even for the expected interest rate at t+i for large i, it is not necessary to assume market participants believed the Fed was more likely to revise its target growth path in order to explain the greater responses found in the empirical studies.

Equations (24) and (25) can be used to determine the effect of a rise in q. Since Fed policy, during the period studied in the empirical money announcement literature, was aimed at achieving target growth paths for the monetary aggregates, q can be interpreted as an index of the policy's credibility. A high q implies the public expects, with high probability, that deviations from target will be offset. Thus, a rise in q is a rise in credibility. Rewriting (24) and (25) as $\Delta_t i_{t+i} = b(i)\eta_{t-2}$,

$$\partial b(i)/\partial q = -[(1-\lambda)^i \lambda/(1+\alpha\lambda) + \pi] < 0 \qquad (26)$$

for $i \geq N$. Since a rise in q reduces the weight given to the possibility that a money surprise signals a change in the long run rate of inflation, distant expected future interest rates respond less to the new information contained in the announcement.[23]

For $i < N$, the sign of $\partial b(i)/\partial q$ is ambiguous. If prices are slow to adjust so that d(1) approximately equals zero, $\partial b(1)/\partial q = \alpha^{-1}[3\pi - (1-\lambda)]$ which is negative for small π. In this case, <u>greater belief in the monetary authority's commitment to offset money surprises decreases the response of the current short-term</u> rate[24] <u>to the unanticipated component of the weekly money announcement.</u>

Equations (23) and (25) also illustrate the manner in which the real and nominal interest rate responses depend on the a_{it} parameters. Because the new information contained in the money announcement does not allow the individual underlying disturbances to be identified, a positive money surprise is attributed partially to real, permanent income disturbances and partially to money demand shocks. Most previous models of the money announcements have considered only the special case in which the money surprises are caused by money demand shocks (ε_{t-2}), and the money announcement fully reveals ε_{t-2}. In the present framework, this case is the special one in which $a_{1t} = a_{3t} = 0$, and $a_{2t} = 1$. It follows immediately from (22) that expected future real rates are unaffected by money surprises. For large i, equation (24) implies that expected future nominal interest rates will move only if the public believes there is some chance the monetary authority will revise its target growth path. For $i < N$, the last term in both (23) and (25) becomes $\alpha^{-1}(1-d(i))(1-\gamma)\eta_{t-2}$, so that real and nominal interest rates depend only on the permanent component of any disturbance to money demand.

If money announcements provide any information that is useful in forecasting future real income, as suggested by Siegel (1985) and Litterman and Weiss (1985), a_{1t} will differ from zero. The Kalman filter coefficients will depend on the sample estimates of the variances and covariances of the underlying disturbances (see Chow (1975)), and will generally evolve over time. Unobserved shifts in the population variances of these disturbances (σ_ψ^2 and σ_ε^2) will cause movements in the a_{it}'s. For example, suppose the variance of real shocks rises relative to that of nominal money demand shocks. Such a structural shift will cause a_1 to rise and a_2 to fall. From (23) and (25), the response of both real and nominal interest rates will rise in absolute value. <u>An increase in the relative importance of real shocks will cause interest rates to become more sensitive to money surprises.</u>

V. Conclusions

The simple model developed in this paper incorporates most of the competing hypotheses which have been put forward to explain the positive response of nominal interest rates to the unanticipated component of the

Federal Reserve's weekly money announcements.[25] By explicitly modelling these hypotheses, an expression for the response of current and expected future short-term real and nominal interest rates was obtained. The factors emphasized in earlier models of the money announcement effect become special cases in this more general framework. The model shows how empirically estimated interest rate responses depend on the speed with which money supply deviations from target are offset, the credibility of such a policy, and the relative importance of shocks to real, permanent income and nominal money demand.

Few economists would claim that weekly variations in the stock of money have important effects on macroeconomic variables of interest. However, the weekly announcements of the latest figures on M1, together with the availability of survey measures of expectations about the announcements, provide an almost ideal setting for testing hypotheses about the responses of asset prices to new information. Because the announcement provides information about a previous week's money stock, the new information in the announcement is predetermined with respect to the subsequent interest rates movements. In addition, the survey seems to provide a reasonable measure of the market's expectations about the announcements. These properties have made this a useful setting in which to examine hypotheses concerning the role expectations about future policy play in influencing interest rates. While a great deal of empirical evidence has been accumulated documenting the responses of asset prices to the weekly money surprises over several sample periods, the theoretical modelling of these effects has lagged behind. The responses seem to shift with changes in monetary policy, but in order to derive testable hypotheses about the manner in which various characteristics of the environment influence the responses, a more general theoretical framework than has guided the empirical research to date seems necessary. This paper represents a preliminary attempt to provide such a framework.

APPENDIX

Equations (8) and (9) can be evaluated by substituting for $\Delta_t m_{t+i}$ - $\Delta_t p_{t+i} + \Delta_t y^P_{t+i} + \Delta_t u_{t+i}$. From (4)-(6) and (18)-(21), $\Delta_t y^P_{t-2} + \Delta_t u_{t-2} = \eta_{t-2}$, and $\Delta_t y^P_{t-1} + \Delta_t u_{t-1} = \Delta_t y^P_{t-2} + \Delta_t u_{t-2} - \gamma\Delta\varepsilon_{t-2} = (1 - \gamma a_{2t})\eta_{t-2}$, so that

$$\Delta_t y^P_{t+i} + \Delta_t u_{t+i} = \Delta_t y^P_{t-1} + \Delta_t u_{t-1} = (1 - \gamma a_{2t})\eta_{t-2}. \tag{A1}$$

for all $i \geq 0$.

Using (10) and (17),

$$\begin{aligned}\Delta_t m_{t+i} - \Delta_t p_{t+i} &= \Delta_t m_{t+i} - \Delta_t p_{0t+i} - \Sigma_0^N d_s \Sigma_0^\infty b_j\{ \Delta_{t-s+i} m_{t+i} \\ &\qquad - \Delta_{t-s+i} u_{t+j+i} - \Delta_{t-s+i} y^P_{t+j+i}\} - \Delta_t \phi_{t+i} \\ &= \{-\alpha\delta+q(1-\lambda)^i[1-d(i)/(1+\alpha\lambda)] + (1-q)\pi(i+2)(1-d(i)) \\ &\qquad - (1-q)\pi\alpha d(i)\}\eta_{t-2}\end{aligned} \tag{A2}$$

Substituting (A1) and (A2) into (8) yields the expression for $\Delta_t i_{t+i}$ given in equation (25). Note that for $i \geq N$, $d(i) = 1$, so that (A2) simplifies to

$$\Delta_t m_{t+i} - \Delta_t p_{t+i} = \{-\alpha\delta+q(1-\lambda)^i[\alpha\lambda/(1+\alpha\lambda)]-(1-q)\pi\alpha\}\eta_{t-2}.$$

To evaluate anticipated real rates of interest, it is necessary to determine the revision in the expected rate of inflation from t+i to t+i+1:

$$\Delta_t p_{t+i+1} - \Delta_t p_{t+i} = \Sigma_0^i \, d_s \Sigma \, b_j [\Delta_t m_{t+i+1+j} - \Delta_t m_{t+i+j}]$$

$$+ \, d_{i+1} \Sigma \, b_j \Delta_t m_{t+i+1+j}$$

$$= \{-q\lambda(1-\lambda)^i [d(i)/(1+\alpha\lambda)] + (1-q)\pi d(i)$$

$$+ \, d_{i+1}[q(1-\lambda)^{i+1}/(1+\alpha\lambda) + (1-q)\pi(i+3)\}\eta_{t-2}.$$

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Footnotes

1. Recent work documenting the response of various asset prices to the weekly announcement of M1 include Berkman (1978), Conrad (1978), Grossman (1981), Urich (1982), Urich and Wachtel (1982), Roley (1982, 1983), Shiller, Campbell, and Schoenholtz (1983), Roley and Walsh (1983, 1984), Cornell (1983), Loeys (1984), and Gavin and Karamouzis (1984) who examine interest rate responses, Cornell (1982, 1983), Engle and Frankel (1984), and Hardouvelis (1984a) who examine exchange rates and interest rates, and Pearce and Roley (1984) who examine stock prices, and Frankel and Hardouvelis (1985) who examine commodity prices.

2. Such evidence would only be consistent with real rates remaining constant if the aggregate price level jumps in response to weekly money announcements.

3. For example, see Roley and Walsh (1983) or Loeys (1984).

4. See, for example, Campbell (1984) for some empirical evidence.

5. This ignores the existence of unequal reserve ratios on the various components of the money stock and assumes excess reserves are equal to zero.

6. See Goodfriend (1982) for a discussion.

7. Borrowing also depends on the current and expected future value of the discount rate, but this is assumed to be constant and so will be ignored.

8. To ensure stabiltiy of the forward rational expectations solution to (1), it is assumed that $\beta_1 > \beta_2$. For a fuller analysis of discount window borrowing and Federal Reserve policy, see Goodfriend (1982).

9. This point is analyzed by Nichols and Small (1984) and Campbell (1984).

10. This specification differs from that of Nichols, Small, and Webster (1983) and Hardouvelis (1985) who do not include income explicitly and who assume money demand also depends on ${}_ti_{t+1} - i_t$. The money demand equation assumed here is more standard. In Roley and Walsh (1983), the interest rate in the money demand equation is identified with a rate of longer maturity than i_t.

11. Roley and Walsh (1984) regress the change in the 3-month Treasury Bill rate over a settlement week on the contemporaneous unanticipated money stock. The resulting estimated coefficient was positive and significant for the October 1979 to October 1982 period. Similar results were found using the ten-year constant maturity Treasury security yield.

12. Hardouvelis (1985) uses a similar specification. However, his shocks incorporate transitory income shocks as well as money demand

shocks since no income variable is explicitly included in his money demand equation.

13. The models of Urich (1983), Walsh (1983), Nichols, Small, and Webster (1983), and Roley and Walsh (1983, section II) fall into this category.

14. This is because the elasticity of money demand with respect to permanent income is assumed to be equal to one.

15. Since δ depends on the correlation between permanent income and the real rate of interest, it could be either positive or negative.

16. Roley (1983) presents evidence which shows that the interest rate response to a money surprise depends on whether the announcement places the money stock inside, below, or above the policy range.

17. Actually, the announcement represents a preliminary estimate of m_{t-2}. The evidence in Roley and Walsh (1984) suggests the subsequent revisions in these preliminary estimates have no effects on interest rates.

18. This assumption is consistent with empirical evidence that the announcement of the latest figures on the Consumer Price Index have little impact on interest rates. The release of the Producer price Index, however, does seem to affect rates. See Roley and Troll (1983) and Smirlock (1984).

19. It is not necessary for the present analysis to derive explicitly the expectations of the underlying shocks just prior to the money announcement. Note that no revision in either permanent income or the money demand shock (u) from period t-3 appear in (18) since, from (4), the sum of these two is known exactly prior to week t's money announcement.

20. See Chow (1975). For an application to the case in which the money supply is measured with error, see Trevor (1984).

21. The second and third terms in (23) become $-\alpha^{-1}(1-d(i))\gamma a_{2t} \leq 0$.

22. The empirical evidence of increased responses refers to nominal interest rates while (23) gives the real rate response. As discussed earlier, however, the evidence suggests that the nominal rate movements are also real rate movements. The responses implied by the model for nominal rates are considered below.

23. Judd (1984) reports results consistent with this result. After October 1982, when the Fed de-emphasized control of M1, forward rates five years out became more sensitive to money surprises. See also Hardouvelis (1984b) and Loeys (1985).

24. Recall from equation (3) that $\Delta i_t = \beta_1^{-1}\beta_2\Delta_t i_{t+1} = \beta_1^{-1}\beta_2 b(1)\eta_{t-2}$ under a nonborrowed reserves operating procedure.

25. The one explanation discussed by Cornell (1983) which was not included was the uncertainty hypothesis.