NBER WORKING PAPER SERIES

WHY MONEY ANNOUNCEMENTS MOVE INTEREST RATES: AN ANSWER FROM THE FOREIGN EXCHANGE MARKET

Charles Engel

Jeffrey A. Frankel

Working Paper No. 1049

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge MA 02138

December 1982

The idea for this paper originated in a comment made by Ronald McKinnon to one of the authors in 1978. We are also indebted to Robert Flood, James Hamilton, Dale Henderson, Peter Isard, and Maurice Obstfeld for their valuable insights; to Richard Meese for comments on an earlier draft; to Bob Jones of Money Market Services, Inc., for their survey data on money supply expectations; and to the National Science Foundation for research support under grant number SES-8007162, administered through the Institute of Business and Economic Research, University of California, Berkeley. The research reported here is part of the NBER's research program in International Studies. Any opinions expressed are those of the authors and not those of the National Bureau of Economic Research.

NBER Working Paper #1049
December 1982

Why Money Announcements Move Interest Rates: An Answer From The Foreign Exchange Market

ABSTRACT

On a Friday that the Fed announces a money supply greater than had been anticipated, interest rates move up in response. Why? One explanation is that the market perceives the fluctuation in the money stock as an unintended deviation from the Fed's target growth rate that will be reversed in subsequent periods. The anticipation of this future tightening drives up interest rates today. A second explanation is that the market perceives the increase in the money supply as signalling a higher target growth rate. The expected future inflation rate rises, which is reflected in a higher nominal interest rate.

This paper offers grounds for choosing between the two possible explanations: evidence from the exchange market. Under the first explanation, anticipated future tightening, one would expect the dollar to appreciate against foreign currencies. Under the second explanation, expected inflation, one would expect it to depreciate. We render these claims more concrete by a formal model, a generalization of the Dornbusch overshooting model. Then we use the mark/dollar rate to answer the question. We find a statistically significant tendency for the dollar to appreciate following positive money supply surprises. This supports the first explanation.

Charles Engel
Department of Economics
University of Virginia
Charlottesville, VA 22901

(804) 924-3660

Jeffrey Frankel
Department of Economics
University of California
Berkeley, CA 94720

(415) 642-8084

1. Why does the interest rate rise after announcements of money growth?

One striking empirical regularity in recent years has been the tendency for interest rates to rise whenever the Federal Reserve Board announces an increase in the money supply greater than had previously been expected. This relationship appears almost every week in credit market developments as reported in the financial press, and is borne out by Table 4 below.[1] At first glance, the phenomenon might seem puzzling to a student of textbook IS-LM models, which predict that liquidity effects should make interest rates fall when the authorities expand the money supply. At second glance, however, the student should realize that there is not necessarily an inconsistency. Interest rates may indeed fall during a week in which the Fed increases the money supply. But when the announcement occurs ten days later, interest rates will change purely because the announcement alters the market's expectations of future monetary policy.

There is, in fact, an explanation of this weekly occurrence that is consistent with the Keynesian (IS-LM) view that tighter money causes the real interest rate to rise. Money growth that is faster than expected by the market is typically faster than what was expected by the Fed as well. Weekly blips in the money supply are unintended errors--due to fluctuations in private money demand or in the banking system--beyond the monetary authorities' control. The Fed subsequently corrects the errors to bring the money supply back in line with its target growth rates. Thus the announcement of a large money supply increase generates the expectation of future contraction in credit, and higher interest rates. In anticipation, interest rates jump on bonds with terms that include the period in which money markets will be tighter. The fact that rates on even very short-term bonds increase indicates a belief that the Fed wastes no time in beginning to correct errors.[2]

This explanation of the announcement effect on interest rates is commonly given by staff writers of the Wall Street Journal, especially in the Monday column on credit markets.

> The Federal Reserve System may be forced to boost the discount rate from 12% in its battle to halt the soaring growth of the nation's money supply...Fears of Fed credit tightening sent the markets reeling Friday after release of the latest money supply statistics. Prices of long-term U.S. government bonds tumbled by more than a point, or $10 for each $1,000 face amount of securities. Interest rate increases of ½ percentage point were common on short-term securities. (January 25, 1982)

However, there is a second, very different, explanation of the phenomenon that, ironically, is propounded in the same newspaper, but in the editorial column. The announcement of rapid money growth causes the market to raise its estimate of the Fed's target money growth rate, the expected inflation rate rises, and it is reflected in a higher nominal interest rate.

> A reduction in money growth will constrict the supply of credit, but it will also lower inflationary expectations. If the markets are convinced the Fed is really serious about slowing money growth, the drop in the inflationary premium will swamp the impact on the real rate of interest, and nominal rates will fall. This is precisely what seems to be happening this week in the wake of the latest money supply figures. (January 7, 1981)

One might think of other ways of describing the positive correlation between money announcements and interest rate changes. But they can be seen to fall into the category of one or the other of these two competing explanations, if one groups them by reference to the decomposition of the nominal interest rate into the real interest rate and the expected inflation rate. According to the first explanation, a large money announcement raises the nominal interest rate because it raises the real interest rate. We will refer to this as the liquidity effect. According to the second explanation, the announcement raises the nominal interest rate because it raises expected inflation. We will refer to this as the inflation premium effect.

It would be useful to be able to distinguish between the two hypotheses, since they might give an indication of how the market views the Fed's policies. The liquidity effect requires that the market expect the Fed to stick to its pre-announced money growth target and to correct any aberration. The inflation premium explanation implies that the Fed is not trusted to keep a steady course; the market, like the Wall Street Journal editors, is ready to interpret any deviation in money growth as a signal that the Fed is changing its targets.

Fortunately, there is a quite simple way to choose between the two hypotheses. If expected inflation increases, then the value of the dollar should fall (the exchange rate should rise) as demand for the currency declines. On the other hand, if tight monetary policy causes the real interest rate to rise, then a capital inflow should cause an appreciation of the dollar. Thus, if the inflation premium view is correct, the exchange rate should have the same positive correlation with money announcements that the interest rate has. If the liquidity view is correct, the exchange rate should have the opposite correlation with the other variables.[3]

Section 2 of this paper formalizes the intuitive argument that the exchange rate depends on the expected future path of the money supply. The model is a generalization of Frankel's (1979) synthesis of Jacob Frenkel's (1976) monetarist version and Rudiger Dornbusch's (1976) Keynesian version, of the monetary approach to exchange rate determination. The reader familiar with this literature, or willing to accept the intuitive argument, is strongly encouraged to skip directly to the empirical results in Section 3. There, it is discovered that the evidence strongly favors the liquidity effect.

2. A model of the exchange rate's dependence on monetary tightness

In this section we illustrate in a particular model how the exchange rate jumps in response to changes in the general perceived future path of monetary policy. Thus in the case where announcements of unexpectedly large money supplies are interpreted as increases in the Fed's target money growth rate, the exchange rate increases. In the case where such announcements are interpreted as transitory deviations bringing future contraction, the exchange rate falls.

We begin with a conventional money demand equation

(1) $$m_t - p_t = - \lambda i_t + a_t \quad .$$

Here m and p are the logs of the money supply and price level, i is the very short-term interest rate and a_t represents the influence of real income and other exogenous shifts in money demand.

In a flexible-price monetarist world, the combination of purchasing power parity in rate-of-change form and interest rate parity (equation (6) below) would tie the domestic interest rate to the foreign interest rate, with an allowance for expected inflation. Then the domestic price level p_t

would be determined by the money demand equation (1) and a money supply process.

We are going to allow prices to be sticky, to be prevented from jumping at a moment in time. Thus purchasing power parity does not hold in the short run. But prices adjust to excess demand over time, so purchasing power parity does hold in long-run equilibrium:

(2) $$\bar{s}_t = \bar{p}_t ,$$

where $\bar{s}$ is the log of the equilibrium spot exchange rate, $\bar{p}$ is the log of the domestic equilibrium price level, and the log of the foreign equilibrium price level is taken as exogenous and is here normalized at zero. The domestic equilibrium price level is in turn defined by the stable ("no bubble") rational expectations solution to

(3) $$\bar{m}_t - \bar{p}_t = -\lambda[E_t\bar{p}_{t+1} - \bar{p}_t + i^*] + a_t \quad ,$$

where $E_t\bar{p}_{t+1} - \bar{p}_t$ is the equilibrium inflation rate expected at time t and i^* is the foreign interest rate, also taken to be exogenous. This is a logical way to determine $\bar{p}$, because it is the way we would determine p in a flexible-price world.

We find the rational expectations solution as follows. Solve equation (3) for p_t in terms of $E_t\bar{p}_{t+1}$. Then substitute the solution for $E_t\bar{p}_{t+1}$ in terms of $E_t\bar{p}_{t+2}$. Continuing to substitute recursively, we obtain

(4) $$\bar{p}_t = \frac{1}{1+\lambda} \sum_{\tau=0}^{\infty} \left(\frac{\lambda}{1+\lambda}\right)^{\tau} E_t(m_{t+\tau} - a_{t+\tau}) + \lambda i^* \quad .$$

We see that $\bar{p}_t$ is an indicator of how expansionary the entire future path of money supply is expected to be relative to money demand. As an example, if money supply and demand are expected to be constant at m_t and a_t, respectively, then $\bar{p}_t$ is simply $m_t - a_t + \lambda i_t^*$. Below we will consider two alternative specific money supply processes to narrow down the range of possibilities under (4).

Now we are going to see how changes in the unobservable $\bar{p}_t$ are reflected as changes in the observable s_t. We assume a form of regressive expectations for the exchange rate:

(5) $$E_t s_{t+1} - s_t = \theta(\bar{s}_t - s_t) + E_t \bar{s}_{t+1} - \bar{s}_t \ .$$

In the long-run equilibrium, when $\bar{s} - s = 0$, the spot rate s is of course expected to increase at the rate of the equilibrium spot rate $\bar{s}$, which will be the same as the rates of increase of the equilibrium price level (by purchasing power parity) and money supply (by money demand homogeneity). But in the short run, if the spot rate exceeds what the market considers its equilibrium path $(\bar{s} - s < 0)$, then the currency is thought to be "undervalued," and is expected in the future to appreciate $(E_t s_{t+1} - s_t < 0)$ relative to the equilibrium path at a rate that is proportional to the gap. (5) is of the general form that expectations are assumed to take in Frankel (1979) and Mussa (1977). In our appendix it is shown to be precisely the rational form for expectations to take when the system contains an equation specifying the price level to adjust gradually according to an excess demand function plus a term for the equilibrium inflation path.

Our final assumption is uncovered interest partiy:

(6) $$i_t - i^* = E_t s_{t+1} - s_t \ .$$

Return to the money demand function (1). An announcement of monetary growth at time t, as opposed to the event itself over the preceding period, does not change the money supply, or the price level or real money demand, and thus does not change the short-term interest rate i_t.[4] Thus, by (6) it does not change expected depreciation $E_t s_{t+1} - s_t$, which in turn is the establishes that s_t jumps with $\bar{p}_t$. If the announcement of an unexpectedly high money supply induces the public to raise its expectation of future money supplies relative to money demand, a sudden increase in s_t will tell us so. On the other hand, if the announcement induces expectation of monetary contraction in the near future, a sudden fall in s_t will tell us so.

To make these two cases more concrete we now consider two particular alternative money supply processes. Both involve a target path for the money supply with growth rate μ_t :

(9) $$\bar{m}_t = \bar{m}_{t-1} + \mu_t \quad .$$

In both cases we also assume here that real money demand a_t follows a random walk; to get our results (qualitatively) it is sufficient that a_t be autocorrelated. (Recall that a_t includes real income.)

Under money supply process "A," the Fed succeeds in hitting its money supply target even on a weekly basis, but the Fed keeps changing the target growth rate according to a random walk:

(10a) $$m_t = \bar{m}_t$$

(11a) $$\mu_t = \mu_{t-1} + v_t \quad .$$

This implies $E_t m_{t+\tau} = m_t + \tau\mu_t$. If we use this money supply process in equation (4), we find that the announcement of a money supply 1% greater than expected raises $\bar{p}_t$ by $\lambda\%$:[6]

(12a) $$\bar{p}_t - \bar{p}_{t'} = \lambda(m_t - E_{t'} m_t) \quad .$$

Intuitively, under money supply process A , the announcement of m_t is interpreted as a one-for-one increase in the steady-state inflation rate, which reduces steady-state real money demand--or raises the equilibrium price level --by that amount times the semi-elasticity of money demand. From (8):

left-hand side of (5):

$$(5') \qquad 0 = \theta((\bar{s}_t - \bar{s}_{t'}) - (s_t - s_t')) + (E_t\bar{s}_{t+1} - E_{t'}\bar{s}_{t+1}) - (\bar{s}_t - \bar{s}_{t'}) \quad ,$$

where we are using t' to denote the value of a variable the instant before the announcement.[5]

We are interested in the change in the current spot rate induced by the announcement:

$$s_t - s_{t'} = \bar{s}_t - \bar{s}_t' + \frac{1}{\theta}[E_t\bar{s}_{t+1} - E_{t'}\bar{s}_{t+1}) - (\bar{s}_t - \bar{s}_{t'})] \quad .$$

We use (2):

$$(7) \qquad s_t - s_{t'} = \bar{p}_t - \bar{p}_{t'} + \frac{1}{\theta}[(E_t\bar{p}_{t+1} - \bar{p}_t) - (E_{t'}\bar{p}_{t+1} - \bar{p}_{t'})] \quad .$$

The expression in brackets is the revision in the market's expected equilibrium inflation rate. The equilibrium money demand equation (3) tells us, with m_t , i^*_t , and a_t tied down, that the effect of the announcement on the market's expected equilibrium inflation rate is related to the effect on the equilibrium price level:

$$(3') \qquad \bar{p}_t - \bar{p}_{t'} = \lambda[(E_t\bar{p}_{t+1} - \bar{p}_t) - (E_{t'}\bar{p}_{t+1} - \bar{p}_{t'})] \quad .$$

We combine (3') and (7):

$$(8) \qquad s_t - s_{t'} = (1 + 1/\lambda\theta)(\bar{p}_t - \bar{p}_{t'}) \quad .$$

Equation (8) is the promised result that revisions in $\bar{p}$, the indicator of expected future credit conditions, cause proportional jumps in the spot exchange rate. The equation is a generalization of Dornbusch's celebrated overshooting result that an unanticipated increase in the money supply causes an equilibrium increase in the exchange rate of the same percentage, and in addition causes the current exchange rate to overshoot its equilibrium by $1/\lambda\theta$.

We could stop here. Equation (4) establishes $\bar{p}_t$ as an indicator of the entire expected future path of monetary policy and equation (8)

$$(13b) \qquad s_t - s_{t'} = -\frac{1+\lambda\theta}{\theta(1+\lambda)}(m_t - E_{t'}m_t) \quad .$$

In this case, the dollar appreciates with the announcement of an unexpectedly high money supply -- the opposite from case A.

With either money supply process A or B, the nominal rate of interest would increase with a higher-than-anticipated money supply announcement. However, with process A it would be the inflation premium that would rise, while in case B the real rate would jump. (This is demonstrated formally in the Appendix.) The two processes are distinguishable by their differing implications for exchange rate movements.

3. Empirical tests of announcement effects

The market's anticipation of the next money growth announcement is determined not only by the most recent money supply figures, but by many other factors as well. Any attempt to measure expected money growth by, for example, an ARIMA model of the money supply time series, is unlikely to be accurate. It turns out that there is a very convenient measure of the market's opinion of what the Fed is going to announce. Money Market Services, Inc., each week surveys sixty individuals who make predictions of what the announcement will be. It is these survey numbers that we use as our measure of expected money growth.

It would add to the credibility of the survey numbers if we could show that they are unbiased predictors of the actual money supply announcements. Grossman has recently shown that the Money Market Services forecasts are unbiased for the period September 1977-September 1979. Table 1 shows some simple tests performed on an updated time sample. The first regression is a test of whether the mean forecast error from September 1977-

(13a) $s_t - s_{t'} = (\frac{1+\lambda\theta}{\theta})(m_t - E_{t'}m_t)$.

The announcement of an unexpectedly high money supply in this case causes an immediate depreciation of the dollar.

Under the alternative of money supply process "B", the Fed sticks to its pre-set target growth rate, but the actual money supply deviates from the target due to unintended weekly fluctuations:

(10b) $m_t = \bar{m}_t + u_t$

(11b) $\mu_t = \mu$.

If we use this money supply process in equation (4), we find that the announcement of a money supply 1% greater than expected reduces $\bar{p}_t$ by $\lambda/(1+\lambda)$:

(12b) $\bar{p}_t - \bar{p}_{t'} = - \frac{\lambda}{1+\lambda} (m_t - E_{t'}m_t)$.

Intuitively, under money supply process B, the announcement is interpreted as requiring a one-for-one contraction in the following period. It is true that the public has discovered the money supply in the most recent period to be higher than it had estimated. But it necessarily discovers at the same time that money demand a_t is higher than it had thought. Under our assumption that a_t is autocorrelated, the upward shift in money demand is expected to remain next period. But under our assumption of money supply process B, the money supply is anticipated to shift back next period. In expression (4), representing the expected present discounted sum of present and future credit market conditions, expected money supply has fallen relative to expected money demand. This tightening in expectations of monetary policy is reflected in a sudden fall in $\bar{p}_t$. From (8) announcement effect. However, we will certainly not get a perfect fit; other factors will contribute to the changes. The question is whether the errors that do intervene in the relationship are independent of the monetary forecast errors. There is an excellent reason to believe that they are: both the announced money supply figures and their forecasts as measured by Money Market Services are predetermined, by several days, at the time that the announcement is made. A claim of econometric exogeneity on the part of the monetary forecast error can be supported by a Granger causality test. A necessary condition for monetary forecast errors to be exogenous with respect to a particular variable is that, after taking account of the information in the lagged forecast errors, the variable in question does not help predict the forecast error. Table 3 shows that neither the interest rate nor the exchange rate Granger-causes the monetary forecast error.

Having confirmed the desirable properties of the monetary forecasts, we now proceed to the main results of the paper. Table 4 attempts to confirm the empirical regularity on which the paper is predicated: the positive dependence of interest rate changes on monetary announcements. The interest rate is the one-month Eurodollar rate, and we look at the change from 10 a.m. on the day of the announcement (which is made at 4 p.m.) to 10 a.m. the following day. The sample period is restricted to October 1979 to August 1981.[9] The coefficient in the regressions is positive, and, when estimated by Cochrane-Orcutt, is significant at the 90% level. Somewhat stronger results were obtained by Grossman using Treasury bill rates that were recorded at 3:30 p.m. and 5:00 p.m. on announcement days.

Table 5 presents the regression of the change in (the log of) the dollar/mark exchange rate between 12:00 noon the day of the announcement and 12:00 noon the following day, against the monetary announcement fore-

August 1981 was different from zero. The next two equations test for information in lagged forecast errors.[7] In no case is any coefficient significantly different from zero, supporting the unbiasedness of the forecasts.

The money forecasts are actually made on Tuesdays, while money supply figures were released usually on Thursdays until February 1980, and usually on Fridays after then. Ideally, we would like to know the market's guess at the money supply immediately before the announcement. Money Market Services, Inc., believes that little new information comes in between Tuesday and Friday to change market opinions. The previous week's money supply figures have already been released and digested, and most other relevant information, such as observed interest rate changes, should have come in the week that the change in the money supply actually occurred. To test this claim, it is possible to check whether the exchange rate or the interest rate on the morning of the announcement contains any information that would improve the prediction. Table 2 reports regressions of the forecast error on various combinations of the exchange rate and the interest rates, and lagged values of those two variables and the forecast error. F-statistics indicate an inability to reject the null hypothesis that all coefficients including the constant are zero. Thus, these guesses at the soon-to-be-revealed money stock numbers are efficient with respect to some obvious potential sources of information.[8]

Before we examine the effect of monetary announcements (in excess of their forecasted values) on interest rate and exchange rate changes, we should pause to consider why we are treating the monetary forecast errors as the independent variable. If our observations of the financial variables are taken close enough in time, before and after, to the announcement, then we can hope that the changes are explained largely by the supplies, real income levels, interest rates and inflation rates. A significant negative coefficient on the interest rate indicates a rejection of perfectly flexible prices (e.g., Frankel (1979)). One difficulty with this approach is that there are serious simultaneity problems with considering the interest rate and expected inflation rate as independent variables. And instrumental variable techniques are only partial solutions because it is hard to find exogenous variables. (A second difficulty is that the results have proven to be sensitive to the particular currency and sample period chosen.)

The results in Tables 4 and 5, when taken together, provide evidence against the flexible-price view in a context free from simultaneity problems. Given just the positive correlation of monetary announcements and interest rate changes, one could rationalize the flexible-price model by arguing that unanticipated money growth raises expected future money growth and thus raises expected inflation. Given just the negative correlation of monetary announcements and exchange rate changes, one could rationalize the flexible-price model by arguing instead that unanticipated money growth generates the expectation of future contraction, thus reducing the expected inflation. But the two results taken together can only be explained by granting a role to sticky prices and to fluctuations in the real interest rate. Once again: the money growth announcement causes the real interest rate to rise, which explains <u>both</u> the rise in the nominal interest rate and the fall in the exchange rate.

cast error. The coefficient turns out to be negative, and highly significant. So, on days when the money supply figures turn out to be greater than expected, the currency appreciates. This indicates that the real interest rate rises: the nominal interest rate rises because of liquidity effects, not because of the expected inflation premium.

4. Conclusion

The announcement phenomenon is a valuable tool for cutting through the web of simultaneous causality that plagues much of empirical macroeconomics. The negative effect that the announcements have on the exchange rate indicates that the market believes that the Fed has been following a steady money growth policy, at least since October 1979. When the money supply grows more rapidly than had been expected, the market assumes that the Fed will reverse the error in the future, not that it has raised its money growth target. The expectation of future tightening causes the interest rate to rise and the exchange rate to fall.

The results of this paper also shed light on a second issue. It is sometimes claimed that goods prices are flexible, and that fluctuations in the interest rate mostly consist of fluctuations in the expected inflation rate, rather than the fluctuations in the real interest rate that characterize a Keynesian model.[10] In terms of the model developed in Section 2, the speed of adjustment $\dot{\theta}'$ is thought to be close to infinite. Changes in the nominal money supply or expected inflation rate are reflected immediately in the price level and real money supply, and thus have no effect on the real interest rate. One way people have tested this view of the world is to run a regression of the exchange rate against money

(A6) $$p_{t+1} = p_t + (E_t\bar{p}_{t+1} - \bar{p}_t) - \theta(p_t - \bar{p}_t) \quad .$$

Furthermore, substituting long-run PPP (2) and the expectations equation (5),

$$p_{t+1} = p_t - \theta(p_t - \bar{p}_t) + E_t s_{t+1} - s_t + \theta(s_t - \bar{s}_t) \quad .$$

Again, using long-run PPP (2):

(A7) $$p_{t+1} = p_t + E_t s_{t+1} - s_t + \theta(s_t - p_t) \quad .$$

This form of the price-adjustment equation is helpful in deriving the interest-rate relations.

We assume that the n-period ahead interest rate, ${}_n i_t$, is simply the average of the expected one-period rates for the next n-periods.

(A8) $${}_n i_t = \frac{1}{n}[E_t s_{t+n} - s_t] + {}_n i^*_t \ .$$

From (A7):

(A9) $$E_t s_{t+n} = E_t p_{t+n} + (1 - \theta)E_t(s_{t+n-1} - p_{t+n-1}) = E_t p_{t+n} + (1 - \theta)^n (s_t - p_t$$

Then, from (A2):

(A10) $$E_t s_{t+n} = E_t\bar{s}_{t+n} - \frac{1}{\lambda\theta}(E_t p_{t+n} - E_t\bar{p}_{t+n}) = -\frac{1}{\lambda\theta} E_t p_{t+n} + (1 + \frac{1}{\lambda\theta}) E_t\bar{p}_{t+n}$$

Substituting from (A9) and rearranging:

$$E_t s_{t+n} = -\frac{(1-\theta)^n}{1+\lambda\theta}(p_t - s_t) + E_t\bar{p}_{t+n} \quad .$$

Taking expectations at t' and subtracting (and using the fact that $p_t = p_{t'}$):

$$E_t s_{t+n} - E_{t'} s_{t+n} = \frac{(1-\theta)^n}{1+\lambda\theta}(s_t - s_{t'}) + E_t\bar{p}_{t+n} - E_{t'}\bar{p}_{t+n} \quad .$$

Using (A8)

Appendix

In this appendix we show that expectations of the form of (5) are consistent with a Mussa (1981) price-adjustment equation.[11] We also derive the change in the real and nominal interest rates for money supply processes A and B of section 2.

Substitute the uncovered interest parity relation (6) into the money demand function (1), and subtract (1) from (3):

$$0 = p_t - \bar{p}_t - \lambda(E_t s_{t+1} - s_t) + \lambda(E_t \bar{p}_{t+1} - \bar{p}_t) \quad .$$

Using long-run PPP (2):

$$\text{(A1)} \qquad E_t s_{t+1} - s_t - (E_t \bar{s}_{t+1} - \bar{s}_t) = 1/\lambda \; (p_t - \bar{p}_t) \quad .$$

From the expectations relation (5), and (A1), we have:

$$\text{(A2)} \qquad -\frac{1}{\lambda\theta} (p_t - \bar{p}_t) = s_t - \bar{s}_t \quad .$$

Leading (A2) one period, and taking expectations:

$$\text{(A3)} \qquad -\frac{1}{\lambda\theta} E_t(p_{t+1} - \bar{p}_{t+1}) = E_t(s_{t+1} - \bar{s}_{t+1})$$

Subtracting (A2) from (A3) yields:

$$\text{(A4)} \qquad E_t s_{t+1} - s_t - (E_t \bar{s}_{t+1} - \bar{s}_t) = -\frac{1}{\lambda\theta} [E_t(p_{t+1} - \bar{p}_{t+1}) - (p_t - \bar{p}_t)] \quad .$$

Using (A1) and (A4) and rearranging we have:

$$\text{(A5)} \qquad E_t p_{t+1} = p_t + (E_t \bar{p}_{t+1} - \bar{p}_t) - \theta \; (p_t - \bar{p}_t) \quad .$$

(A5) is consistent with a Mussa-type price-adjustment equation:

Since

$$(1 - \theta)^n > 1 - n\theta \quad ,$$

the interest rate will move the same direction as the unexpected change in the money supply. In this case, the rise is entirely attributable to an increase in the inflation premium since:

$$\text{(A17a)} \qquad {}_nr_t - {}_nr_{t*} = \alpha_1(m_t - E_{t'}m_t) \; ; \; \alpha_1 = \frac{((1-\theta)^n - 1)(1+\lambda\theta)}{n\theta} < 0 \quad ,$$

$$\text{(A18a)} \qquad {}_n\pi_t - {}_n\pi_{t'} = \beta_1(m_t - E_{t'}m_t) \; ; \; \beta_1 = \frac{n + \lambda(1 - (1-\theta)^n)}{n} > 0 \quad .$$

For money supply process B,

$$\text{(A15b)} \qquad E_t\bar{p}_{t+n} - E_{t'}\bar{p}_{t+n} = -(m_t - E_tm_t) \quad .$$

So, from (13b) and (A11):

$$\text{(A16b)} \qquad {}_ni_t - {}_ni_{t'} = \frac{(1-\theta) - (1-\theta)^n}{n\theta(1+\lambda)} (m_t - E_{t'}m_t) \quad .$$

Since

$$(1 - \theta) > (1 - \theta)^n$$

this model is also adequate to explain the observed movements of interest rates on days of monetary announcements. In this case, though, the nominal rate rises because of an increase in the real rate:

$$\text{(A17b)} \qquad {}_nr_t - {}_nr_{t'} = \alpha_2(m_t - E_{t'}m_t) \; ; \; \alpha_2 = \frac{(1 - (1-\theta)^n)(1+\lambda\theta)}{n(1+\lambda)} > 0$$

$$\text{(A18b)} \qquad {}_n\pi_t - {}_n\pi_{t'} > \beta_2(m_t - E_{t'}m_t) \; ; \; \beta_2 = \frac{-(1 + \lambda(1 - (1-\theta)^n)}{n(1+\lambda)} < 0 \quad .$$

(A11) $${}_n i_t - {}_n i_{t'} = \frac{1}{n}\left[\frac{(1-\theta)^n}{1+\lambda\theta} - 1\right](s_t - s_{t'}) + \frac{1}{n}\left[E_t\bar{p}_{t+n} - E_{t'}\bar{p}_{t+n}\right] .$$

Let the n-period real interest rate be ${}_n r_t$:

(A12) $${}_n r_t = {}_n i_t - \frac{1}{n}\left[E_t p_{t+n} - p_t\right] .$$

From (A8) and (A9)

$${}_n i_t - {}_n i_{t'} = \frac{1}{n}\left[(E_t s_{t+n} - E_{t'} s_{t+n}) - (s_t - s_{t'})\right]$$

$$= \frac{1}{n}(E_t p_{t+n} - E_{t'} p_{t+n}) + \frac{1}{n}((1-\theta)^n - 1)(s_t - s_{t'}) .$$

So we get

(A13) $${}_n r_t - {}_n r_{t'} = \frac{(1-\theta)^n - 1}{n}(s_t - s_{t'}) .$$

Since $(1-\theta)^n - 1 < 0$, the exchange rate always moves the opposite direction of the real rate of interest when new money stock figures are revealed.

Let ${}_n \pi_t$ be the inflation premium on n-period bonds:

$${}_n \pi_t = \frac{1}{n}(E_t p_{t+n} - p_t) .$$

Subtracting (A13) from (A11), it follows from (A12):

(A14) $${}_n \pi_t - {}_n \pi_{t'} = \frac{1}{n}\left[\frac{-\lambda\theta(1-\theta)^n}{1+\lambda\theta}\right](s_t - s_{t'}) + \frac{1}{n}\left[E_t\bar{p}_{t+n} - E_{t'}\bar{p}_{t+n}\right] .$$

For money supply process A, it can be shown from (4)

(A15a) $$E_t\bar{p}_{t+n} - E_{t'}\bar{p}_{t+n} = (n+\lambda)(m_t - E_{t'}m_t) .$$

Substituting (A15a) and (13a) into (A11) we get:

(A16a) $${}_n i_t - {}_n i_{t'} = \frac{(1-\theta)^n + n\theta - 1}{n\theta}(m_t - E_{t'}m_t) .$$

J. Grossman (1981), "The 'Rationality' of Money Supply Expectations and the Short-Run Response of Interest Rates to Monetary Surprises," Journal of Money, Credit and Banking, November 1981, 13, 409-24.

G. Hardouvelis (1982), "Market Perceptions of Federal Reserve Policy: A View from the Weekly Money Announcements," U.C. Berkeley, September 1982.

M. Mussa (1977), "Real and Monetary Factors in a Dynamic Theory of Foreign Exchange," University of Chicago, April 1977.

__________ (1981), "Sticky Prices and Disequilibrium Adjustment in a Model of the Inflationary Process," American Economic Review, December 1981, 71, 1020-27.

C. Nelson and G.W. Schwert (1977), "Short-Term Interest Rates as Predictors of Inflation: On Testing the Hypothesis that the Real Rate of Interest is Constant," American Economic Review, June 1977, 67, 478-486.

D.A. Nichols and D.H. Small (1982), "Why Interest Rates Rise When an Unexpectedly Large Money Stock is Announced," University of Wisconsin, January 1982. American Economic Review, forthcoming.

D. Pierce (1981), "Trend and Noise in the Monetary Aggregates." In New Monetary Control Procedures, Vol. II, Federal Reserve Staff Study (Feb.)

V. Roley (1982), "Weekly Money Supply Announcements and the Volatility of Short-Term Interest Rates," Federal Reserve Bank of Kansas City Economic Review, April 1982.

T.J. Urich (1982), "The Information Content of Weekly Money Supply Announcements," Journal of Monetary Economics, Vol. 10, no. 1, July 1982, pp. 73-88.

T. Urich and P. Wachtel (1981), "Market Responses to the Weekly Money Supply Announcements in the 1970's," Journal of Finance, Vol. 36, no. 5, December 1981, pp. 1063-72.

References

W. Conrad (1981), "Treasury Bill Market Response to Money Stock Announcements," Federal Reserve Board, 1981.

B. Cornell (1982a), "Money Supply Announcements and Interest Rates: Another View," UCLA Working Paper, March 1982.

__________ (1982b), "Money Supply Announcements, Interest Rates, and Foreign Exchange," Journal of International Money and Finance, August 1982, pp. 201-208.

R. Dornbusch (1976), "Expectations and Exchange Rate Dynamics," Journal of Political Economy, December 1976, 84, 1161-76.

C. Engel (1981), "Money Announcements, Interest Rates and Exchange Rates," U.C. Berkeley, December 1981.

E. Fama (1975), "Short-term Interest Rates as Predictors of Inflation," American Economic Review, 1975, 65, 269-82.

J. Frankel (1979), "On the Mark: A Theory of Floating Exchange Rates Based on Real Interest Differentials," American Economic Review, September 1979, 69, 610-22.

J. Frenkel (1976), "A Monetary Approach to the Exchange Rate: Doctrinal Aspects and Empirical Evidence," Scandinavian Journal of Economics, May 1976, 78, 200-24.

__________ (1981), "Flexible Exchange Rates, Prices, and the Role of 'News': Lessons from the 1970s," Journal of Political Economy, August 1981, 89, 4, 665-705.

C. Granger (1969), "Investigating Causal Relations by Econometric Models and Cross-spectral Methods," Econometrica, July 1969, 37, 424-38.

</ref_section>

A possible alternative solution to the problem is to abandon the requirement that the money demand equation hold exactly in the short run and to model explicitly the money multiplier process as a simultaneous equation in m , the current i , and the i's expected to prevail later in the week or month. Banks react to a monetary announcement by expecting, e.g., contraction and a higher Fed funds rate later in the week, and thus by raising their demand for reserves today, raising the Fed funds rate (and lowering m) today. The fact that banks are allowed to average their reserve holdings out over the week to meet reserve requirements explains why they would drive today's Fed funds rate up to the level expected to prevail later in the week. We are indebted to Dale Henderson for the banking story.

5. Between $t - 1$ and t' the money supply changes occur and the money demand errors occur. The announcement is made at t . The symbol t' is really only a handy device that designates the values of the variables that would hold at time t , if no money announcement had been made. Thus, $t + 1$ is exactly one period away from t' for purposes, say, of calculating interest rates.

6. We have used the fact that $(m_t - E_{t'}m_t) = (a_t - E_{t'}a_t)$, i.e., that the market's revision of the expected money supply carries with it a matching revision in expected money demand. This follows from the assumptions that prices are sticky, interest rates are observable, and the money demand equation (1) holds.

Presumably the market has already used changes in the interest rate observed during the week to estimate money supply less money demand, with the breakdown (as to how much each is estimated to have changed) depending ra-

Footnotes

1. The positive effect of unanticipated money announcements on interest rate changes has also been documented recently by William Conrad (1981), who uses an ARIMA process to measure expected money growth, and J. Grossman (1981), who uses the same survey numbers that we do. More recently, it has also been documented by Vance Roley (1982), Thomas Urich and Paul Wachtel (1981), Urich (1982), Bradford Cornell (1982a), and Gikas Hardouvelis (1982).

2. This explanation is developed theoretically by Donald Nichols and David Small (1982), as well as by many of the empirical papers listed in footnote 1.

3. The first version of this paper appeared January 4, 1982. Since then, Bradford Cornell (1982b) has written a very similar paper.

4. One might legitimately ask how we hope to explain announcement effects on the interest rate if it is tied down by the money demand equation. The rationalization we are using here is that the interest rate i_t that gives us instantaneous money market equilibrium is a very short-term interest rate -- shorter-term than the one-month short-term interest rate represented by our data. An announcement that raised or lowered expected future money growth could raise or lower the value that i is expected to have later in the month (when p has had time to adjust fractionally), and thus raise or lower today's one-month rate, without changing today's i. The disadvantage with this rationalization is that announcement effects are in fact observed for interest rates with a term as short as one day, e.g. the Fed funds rate.

tion to do so. Thus it seems appropriate to consider the post-October period alone.

10. For example, Fama (1975) and Frenkel (1981). Of course there already exists other evidence against the Fama view. See, for example, Nelson and Schwert (1977).

11. In other words, our expectation equation (5) is of the form that is rational in a system that includes a price-adjustment equation of the Mussa form. An alternative way of showing this would be to begin with a price-adjustment equation of the Mussa type and derive the rational expectations solution. This is how Engel (1981) proceeds.

tionally on the relative variance of the two. Still, the market gains a lot of information when the true money supply is announced. When it does, the revisions in its estimates of money supply and money demand must be equal.

7. The forecast error is the log of the actual announced money supply minus the log of the predicted money supply. Actually, Money Market Services, Inc., supplied predicted changes in the money supply. These figures were added to the current revised figures for the previous week, reported in the Federal Reserve Bulletin, to get the predicted money supply.

8. In light of our finding that the survey data appear to be unbiased predictors of the actual money supply figures, one might be tempted to assume rationality of expectations, and to examine the actual money supply process directly. For example Pierce (1981) has found that the purely transitory component is responsible for a standard deviation of $\pm$ \$3.3 billion in the weekly money supply figures. However, the existence of transitory deviations in the money supply is not sufficient to imply the announcement effect on interest rates. We would also need positive autocorrelation in money demand innovations, as in the model of section 2 (or in the banking system innovations, as in footnote 2). Simultaneous estimation of money supply and demand equations might answer the question, but the technique used here is cleaner and easier.

9. The Federal Reserve Board changed its operating procedure on October 6, 1979, abandoning the use of interest rates as a guide to intervention in money markets. The aim of this policy change, of course, was to enable it to hit its money growth targets in the future, an aim that it had often failed to achieve in the past, and to convince the market of its determina-

Table 3
Causality Test
(Dependent variable: MFE_t = logarithmic monetary forecast error at t)

									R^2	D.W.
1.	c	MFE_{-1}	MFE_{-2}	MFE_{-3}	MFE_{-4}	MIN_{-1}	MIN_{-2}			
	.0073	-.154	-.024	-.038	-.089	-.023	-.041			
	(.0033)	(.108)	(.115)	(.116)	(.112)	(.059)	(.083)			
		MIN_{-3}	MIN_{-4}	MIN_{-5}	MIN_{-6}					
		-.064	-.022	.086	-.030			F(6,86) = 1.50	.115	1.99
	c	MFE_{-1}	MFE_{-2}	MFE_{-3}	MFE_{-4}	MEX_{-4}	MEX_{-2}			
	.0017	-.069	.065	.0071	.083	.0042	-.084			
	(.0038)	(.107)	(.109)	(.109)	(.106)	(.037)	(.053			
		MEX_{-3}	MEX_{-4}	MEX_{-5}	MEX_{-6}					
		-.140	-.0060	-.054	.0019			F(6,86) = 1.44	.121	2.02
		(.053	(.055)	(.054)	(.058)					

Sample Period: October 1979 - August 1981

Table 4
(Dependent variable: one-day change in eurodollar rate)

Regression technique	MFE	D.W.	$\hat{\rho}$	R^2
1. OLS	.236 (.138)	1.099		.007
2. CORC	.162 (.110)		.456 (.091)	.206

Sample period: October 1979 - August 1981

Table 5
(Dependent variable: one-day change in log exchange rate)

Regression technique	MFE	D.W.	R^2
OLS	-.393 (.145)	1.729	.069

Sample Period: October 1979 - August 1981

Table 1

(Dependent variable: MFE_t = logarithmic monetary forecast error at t)

	c	MFE_{-1}	MFE_{-2}		R^2	D.W.
1.	-.00042 (.00035)			F(1,203) = 1.42	0	2.05
2.	-.00042 (.00036)	-.028 (.071)		F(2,201) = 0.76	.0008	2.00
3.	-.00041 (.00036)	-.028 (.071)	.014 (.072)	F(3,199) = 0.49	.0010	1.99

Sample period: Sept. 1977 - Aug. 1981, weekly data
(Standard errors reported in parentheses.)

Table 2

(Dependent variable: MFE_t = logarithmic forecast error at t)

	c	MFE_{-1}	MIN	MIN_{-1}	MEX	MEX_{-1}		R^2	D.W.
1.	-.00058 (.001)		.0014 (.0092)				F(2,202) = 0.72	.0001	2.05
2.	-.00048 (.0011)		.035 (.048)	-.035 (.048)			F(3,200) = 0.63	.0027	2.07
3.	-.00057 (.0011)	-.028 (.071)	.0013 (.0093)				F(3,200) = 0.50	.0009	2.00
4.	.00070 (.0025)				.0017 (.0037)		F(2,202) = 0.81	.0010	2.05
5.	.00069 (.0026)				-.0019 (.024)	.0035 (.024)	F(3,200) = 0.52	.0010	2.05
6.	.00066 (.0025)	-.029 (.071)			.0016 (.0037)		F(3,200) = 0.56	.0017	1.99
7.	.00054 (.0026)		.0020 (.0093)		.0018 (.0037)		F(3,201) = 0.55	.0012	2.05

Sample period: Sept. 1977 - Aug. 1981, weekly data
MIN = 1-month eurodollar rate on announcement morning
MEX = log New York market bid exchange rate, announcement morning