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Exchange Rates, Interest Rates, and Money-Stock Announcements: a Theoretical Exposition

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When the Federal Reserve announces a larger than anticipated weekly level of the US money stock (M1) the dollar appreciates and short-term interest rates increase because of an expected liquidity effect, but long-term interest rates and particularly long-run forward interest rates increase because of an expected inflation effect. The two effects are not mutually exclusive but coexist when market participants are not completely sure of the Fed's policy rule, and thus react in a weighted average manner with weights that reflect subjective probabilities about different Federal Reserve money growth policies.

The reaction of exchange rates and interest rates to the weekly Federal Reserve announcements of the US money stock is well documented in the literature. Cornell (1982), Engel and Frankel (1984), and Hardouvelis (1984a) report that the dollar appreciates (depreciates) and short-term interest rates increase (decrease) after an unanticipated announced increase (decline) in M1. The hypothesis proposed to explain these reactions is the 'Expected Liquidity' hypothesis. According to this hypothesis, an unanticipated, say, increase in M1 is expected to persist. By definition, the surprise about M1 represents an equal surprise about money demand and money supply. However, market participants anticipate the change in money demand to be more persistent than the change in money supply. This is because they trust the Fed's pre-announced annual targets and believe that unanticipated changes in the money supply are of temporary nature. Thus an unanticipated increase in M1 provides a signal of a larger future money demand relative to money supply. Given that prices are not perfectly flexible in the short run, future real short-term interest rates are expected to rise to clear the money market. This anticipation drives interest rates up and appreciates the dollar immediately after the announcement.

Both Cornell (1983a) and Hardouvelis (1984a) have noted, however, that the

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strong reaction of long-term interest rates to the announcement of M1 is inconsistent with the Expected Liquidity hypothesis. Hardouvelis showed that *forward* interest rates as far as five years into the future continue to react to the announcement of M1. This reaction would be consistent with the Expected Liquidity hypothesis only under extreme assumptions, *i.e.*, that prices are rigid for a very long time or that the Fed waits for a long time in order to counteract deviations from its targets.

The strong reaction of long-term interest rates appears consistent with the hypothesis that inflationary expectations change. This 'Expected Inflation' hypothesis presumes that the unanticipated change in M1 represents a persistent shock on the growth rate of the money supply. Markets do not trust the Fed's pre-announced targets and revise their inflationary expectations very easily. However, the Expected Inflation hypothesis predicts that the dollar ought to depreciate after an unanticipated increase in M1, which is inconsistent with the data. Thus neither hypothesis, when taken in isolation, is consistent with all market reactions. Cornell claims this is a puzzle.

The present paper presents a formal model with predictions that are consistent with both the spot exchange rate reactions and the long-term interest rate reactions. Thus it resolves the 'puzzle'. The hypothesis underlying the model is a combination of the Expected Liquidity and the Expected Inflation hypothesis. It is argued that markets do not completely trust the Fed's pre-announced targets and attach a small positive probability on the event that the Fed has revised its money growth targets. An Expected Inflation effect coexists with an Expected Liquidity effect. The former is the only effect present in the long-run market reactions but the latter is dominating the short-run market reactions. These notions are formally introduced by postulating a two-part money supply process. The two types of shocks which affect the supply of money are persistent shocks on the growth rate of the money supply, and persistent shocks on the level of the money supply. When combined with the shocks on the demand for money the former give rise to an Expected Inflation effect, while the latter give rise to an Expected Liquidity effect. When M1 is announced market participants cannot distinguish between the two types of money supply shocks. Thus they react in a weighted average fashion with weights which reflect their subjective probabilities about the occurrence of each shock. It is shown how the model's weighted average reaction is consistent with the observed market reactions.

Previous researchers have constructed models of the market reactions to the announcement of M1 which can be viewed as extended special cases of the present model. Urich (1982) and Nichols, Small, and Webster (1983) have constructed models of the reaction of short-term interest rates in which output prices are fixed. Roley and Walsh (1983) have constructed two separate models of the reaction of interest rates, one under rigid and another under flexible prices. Engel and Frankel (1984) have provided the most generalized model so far. It explains both the exchange-rate and interest-rate reactions to the announcement of M1, and allows prices to be rigid in the short run but flexible in the long run. However, they have not extended their analysis to incorporate the simultaneous existence of an Expected Liquidity and an Expected Inflation effect.[1] Their model also depends on the assumption that the very short-term interest rate does not change after the announcement of M1 which is inconsistent with the evidence.

The rest of the paper is organized as follows: Section I contains the description and the solution of the model. Section II examines the model's predictions about the exchange and interest-rate reactions to the announcement of M1. It is shown that the Expected Liquidity and the Expected Inflation hypotheses are two special cases of the general market reaction. Section III presents the conclusion.

I. The Model

I.A. Description

The problem is modeled in discrete time. As Nichols, Small and Webster (1983), I assume that the demand for money is a decreasing function of the expected one-period rate of return on competing assets, say bills and bonds. Bills mature in one week, at the end of period t, and their one-period rate of return, i_t, is known with certainty. Bonds mature in two weeks, at the end of period $t+1$, and their one-period rate of return is uncertain because of possible capital gains or losses when they are sold at the end of period t. Thus bonds add an extra term to the money demand function, which depends on the capital gains component, $t_t - E_t i_{t+1}$. The demand for money is as follows.

$$\langle 1 \rangle \qquad m_t = p_t - a i_t - b(i_t - E_t i_{t+1}) + d_t,$$

where m_t is the logarithm of the nominal demand for money; p_t is the logarithm of the price level; i_t is the one-period nominal interest rate; $E_t i_{t+1} = E(i_{t+1} | I_t)$: the mathematical expectation of i_{t+1} conditional on information available at t; d_t is a shock on money demand which reflects unobserved factors such as real income; and a and b are positive constants. The two components of the demand for money can also be interpreted as the traditional liquidity and speculative demand for money.

The capital gains (speculative) component $i_t - E_t i_{t+1}$ complicates slightly the solution because it makes the money demand equation dynamic. Today's one-period interest rate, i_t, is no longer a function of this week's levels of money demand and money supply only, but it also depends on the expected future path of the demand and supply of money. Thus the announcement of M1 which provides information about the future path of money demand and money supply can affect the one-period interest rate in the model. The capital gains term does not play any further critical role in the main propositions derived from the model. This can be easily checked later by setting the parameter b equal to zero.

The money demand shock is assumed to follow a random walk:

$$\langle 2 \rangle \qquad d_t = d_{t-1} + u_t; \qquad u_t \sim N(0, \sigma_u^2).$$

For the purposes of the model, it is only necessary that d_t be positively autocorrelated.

The price level p_t is not perfectly flexible in the short run. It is set in overlapping contracts as follows:

$$\langle 3 \rangle \qquad p_t = \theta E_{t-2} e_t + (1-\theta) E_{t-1} e_{t+1},$$

where e_t is the logarithm of the exchange rate (the price of foreign currency in terms of US dollars) of period t. The parameter θ equals 1/2, that is, half of the contracts are set each period. Later I will discuss two other possible values that θ can take in this mode, namely $\theta = 0$ and $\theta = 1$. $E_{t-2}e_t$ is the market expectation during period $t-2$ of the equilibrium price level of period t, *i.e.*, the price consistent with purchasing power parity: $E_{t-2}e_t = E_{t-2}(e_t + p_t^*)$, where $p_t^* = 0$ because the foreign price level is normalized to unity. The price rule ⟨3⟩ is only one of many possible ways to introduce price rigidity into the model.[2] It is chosen because it simplifies the algebraic expressions that follow without compromising the intuition which drives the model.

Nominal interest rates and exchange rates are related through the Open (Uncovered) Interest Parity condition:

$$\langle 4 \rangle \qquad i_t - i^* = E_t e_{t-1} - e_t,$$

where i^*, the foreign interest rate, is assumed constant at every period.[3]

The model is closed after defining the money supply equation and assuming that equilibrium holds in the money market. Following Mussa (1975), I specify the money supply process as a two-part process:

$$\langle 5 \rangle \qquad m_t = m_{t-1} + g_t + s_t - cs_{t-1}; \qquad s_t \sim N(0, \sigma_s^2);$$

$$\langle 6 \rangle \qquad g_t = g_{t-1} + v_t; \qquad v_t \sim N(0, \sigma_v^2).$$

The v_t shocks affect the growth rate of the money supply permanently and give rise to an Expected Inflation effect. The s_t shocks affect the growth rate of the money supply only temporarily. However, they affect the level of the money supply permanently by an amount equal to $(1-c)s_t$ and give rise to an Expected Liquidity effect. Notice that the money demand shocks u_t are more persistent than the money supply shocks s_t. The parameter c, $0 < c < 1$, is a measure of how much more persistent shocks on the level of money demand are than shocks on the level of the money supply.

I.B. Solution

For notational simplicity define $x_t \equiv m_t - d_t + ai^*$. Substituting equations ⟨3⟩ and ⟨4⟩ into equation ⟨1⟩, moving forward n periods and taking expectations with respect to information available at time t:

$$\langle 7 \rangle \quad (a+b+\theta)E_t e_{t+n} - (a+2b+\theta-1)E_t e_{t+n+1} + bE_t e_{t+n+2} = E_t x_{t+n}; \qquad n \geqslant 2$$

This is a second order forward looking difference equation in $E_t e_{t+n}$. Its roots are:

$$\langle 8 \rangle \qquad q_{1,2} = [2(a+b+\theta)]^{-1}[a+2b+\theta-1 \pm ((a+\theta-1)^2 - 4b)^{1/2}].$$

As long as $(a+\theta-1)^2 > 4b$ the roots are real. Notice that $0 < q_2 < q_1 < 1$. Solving ⟨7⟩ gives:

$$\langle 9 \rangle \qquad E_t e_{t+n} = [(a+b+\theta)(q_1 - q_2)]^{-1} \sum_{j=0}^{\infty} [(q_1^{j+1} - q_2^{j+1})E_t x_{t+n+j}]; \qquad n \geqslant 2$$

The specific solutions of $E_t e_{t+1}$ and e_t can be found from the following equations:

$$\langle 10\rangle \qquad (a+b)E_t e_{t+1} = -\theta E_{t-1}e_{t+1} + (a+2b+\theta-1)E_t e_{t+2} - bE_t e_{t+3} + E_t x_{t+1},$$

$$\langle 11\rangle \qquad (a+b)e_t = -\theta E_{t-2}e_t - (1-\theta)E_{t-1}e_{t+1} + (a+2b)E_t e_{t+1} - bE_t e_{t+2} + x_t.$$

Equations ⟨10⟩ and ⟨11⟩ depend on the pre-determined at time t values $E_{t-1}e_{t-2}e_t$. These follow difference equations similar to ⟨7⟩. Since they are pre-determined they are unaffected by the announcement of M1 at time t, and there is no need to incorporate their explicit solution into the equations. The above equations reveal that the spot exchange rate depends on the current and expected future path of the money supply relative to money demand.

Using the autocorrelation properties of the money supply and money demand shocks it is straightforward to express the expected values of future money supply and money demand in terms of expectations of current money supply and money demand and current shocks. From equations ⟨2⟩, ⟨5⟩, and ⟨6⟩ it follows that:

$$\langle 12\rangle \qquad E_t x_{t+n} = E_t x_t - cE_t s_t + nE_t g_t.$$

Substituting equation ⟨12⟩ in equations ⟨9⟩, ⟨10⟩, and ⟨11⟩ we get:

$$\langle 13\rangle \qquad e_t = (a+b)^{-1}[-\theta E_{t-2}e_t - (1-\theta)E_{t-1}e_{t+1} + x_t + k_1 E_t x_t - ck_1 E_t s_t + k_2 E_t g_t]$$

$$k_1 = (a+b)^{-1}(a+2b)(a+b+\theta) - b$$

$$k_2 = (a+b)^{-1}(a+2b)(a+b+\theta)(a+\theta) - b(1+a+\theta)$$

$$\langle 14\rangle \qquad E_t e_{t+1} = (a+b)^{-1}[-\theta E_{t-1}e_{t+1} + (a+b+\theta) \times (E_t x_t - cE_t s_t + (a+\theta)E_t g_t)]$$

$$\langle 15\rangle \qquad E_t e_{t+n} = E_t x_t - cE_t s_t + (n+a+\theta-1)E_t g_t; \qquad n = 2, 3, \ldots$$

The solution for the current one-period interest rate as well as current interest rates of maturity longer than one period can be found by using equations ⟨13⟩–⟨15⟩ and the open (uncovered) interest parity conditions. I will assume that long-term interest rates are averages of short-term interest rates and expected future short-term interest rates, *i.e.*, $i_t^{(n)} = (1/n)(i_t + E_t i_{t+1} + \cdots + E_t i_{t+n-1})$.[4] Long-term interest rates can therefore be expressed as follows:

$$\langle 16\rangle \qquad i_t^{(n)} = i^* + (1/n)(E_t e_{t+n} - e_t); \qquad n = 1, 2, 3, \ldots$$

Equations ⟨13⟩–⟨16⟩ reveal that spot exchange rates as well as spot interest rates of different maturities depend both on the actual unobserved current shocks on money supply and money demand, and on the market expectations of these shocks.

Before deriving the market reactions to the announcement of M1 observe that a current under-(over-) estimate of the money supply implies an under-(over-) estimate of money demand of equal magnitude. This intuitive fact which was mentioned earlier in the introductory section can now be derived formally from equation ⟨13⟩ by taking expectations conditional on information available at t and subtracting the result from ⟨13⟩: $m_t - E_t m_t = d_t - E_t d_t$.

II. Market Reactions to Money Announcements

For simplicity assume that the Fed intervenes in the market and affects the supply of money, m_t, during the first business day of fiscal week t. During that day economic agents accumulate money balances in order to spend them later in the week. Thus the unobservable shocks on money demand and money supply have an immediate observable effect on asset prices. At the end of the same day the Fed announces the predetermined level of m_t.[5] The Fed does not intervene in the market again until the first day of fiscal week $t+1$. Thus the supply of money stays constant, at the announced level, throughout fiscal week t. Private markets convene for a second time, however, because market participants have an incentive to trade. The announcement of m_t provides useful information on the unobserved shocks to money supply and money demand and, therefore, on the future evolution of the supply and demand for money. Asset prices change because they depend on the expected future path of the supply and demand for money. After financial markets meet for a second time, they do not reopen until the first business day of fiscal week $t+1$.[6]

Let D denote the difference operator that measures the change of a market variable at the instant of the announcement, *i.e.*, between the two times markets convene. Let t' denote the time at the instant before the announcement of m_t. At t' markets observe the spot exchange rate, $e_{t'}$, and the various interest rates of different maturities, $i_{t'}^{(n)}$. They also know the past levels of the money stock as well as past market variables. First, I examine the two polar cases of the Expected Liquidity and the Expected Inflation effects, then the general case.

II.A. The Expected Liquidity Effect

The Expected Liquidity effect arises in the special case when the only shocks to the money supply process are of the s_t type. In this case $s_t - E_{t'} s_t = m_t - E_{t'} m_t$, and from equations ⟨13⟩–⟨15⟩ we get:

$$De_t = -c[1+(a+b)^{-2}(a+2b)\theta](m_t - E_{t'} m_t) \tag{17a}$$

$$DE_t e_{t+1} = -c[1+(a+b)^{-1}\theta](m_t - E_{t'} m_t) \tag{18a}$$

$$DE_t e_{t+n} = -c(m_t - E_{t'} m_t); \qquad n = 2, 3, \ldots \tag{19a}$$

An unanticipated announced increase (decrease) in the stock of money results in an appreciation (depreciation) of the dollar, which is in accordance with the empirical evidence. In the model, a positive surprise about m_t is interpreted as evidence of a future restriction in liquidity because future money demand is expected to increase by more than future money supply. In order to clear the money market future domestic output prices are expected to decrease and, therefore, the future value of the dollar is expected to go up. Notice that e_t and $E_t e_{t+1}$ appreciate by more than $E_t e_{t+n}$, $n=2, 3, \ldots$. This is due to the two-period price rigidity of the model. Today's exchange rate overshoots its equilibrium value because it carries a larger burden in clearing today's money market.

The reaction of interest rates can be found from equations ⟨17a⟩–⟨19a⟩ and the open (uncovered) interest parity conditions ⟨4⟩ and ⟨16⟩:

⟨20a⟩ $$Di_t = (a+b)^{-2} bc\theta(m_t - E_{t'} m_t)$$

⟨21a⟩ $$DE_t i_{t+1} = (a+b)^{-1} c\theta(m_t - E_{t'} m_t)$$

⟨22a⟩ $$DE_t i_{t+n} = 0; \qquad n = 2, 3, \ldots$$

⟨23a⟩ $$Di_t^{(n)} = (1/n)(a+b)^{-2}(a+2b)c\theta(m_t - E_{t'} m_t); \qquad n = 2, 3, \ldots$$

A positive surprise about m_t signals a higher future money demand than money supply and in the face of price rigidity, higher short-term interest rates. However, when prices become completely flexible (*i.e.*, after two periods in the model), expected future short-term interest rates do not change. Since long-term interest rates, $i_t^{(n)}$, are averages of short-term interest rates and expected future short-term interest rates, they also rise but by a smaller magnitude. As the time to maturity n increases, the magnitude of the reaction decreases. In the limit when $n \to \infty$, $Di_t^{(n)} \to 0$. It is exactly this property of the Expected Liquidity hypothesis which is refuted by the data. The data show that for very large values of n, there continues to be a strong positive reaction.

Real interest rates respond much more than nominal interest rates. This is because the short-run expected rate of inflation moves in the opposite direction from the direction nominal interest rates move. The one period real interest rate, r_t, is by definition equal to $i_t - (E_t p_{t+1} - p_t)$. Therefore $Dr_t = Di_t + (1-\theta)c(m_t - E_{t'} m_t)$. Similarly, for real interest rates $r_t^{(n)}$ of longer maturity: $Dr_t^{(n)} = Di_t^{(n)} + c/n(m_t - E_{t'} m_t)$; $n=2, 3, \ldots$.

The larger the parameter c, *i.e.*, the more persistent money demand shocks are than money supply shocks, the larger the change in the value of the dollar and the larger the change in interest rates. Also, when $\theta = 1$ the market responses are stronger. In this case all contracts are set two periods in advance and the price rigidity is stronger. Conversely, if $\theta = 0$, *i.e.*, when there is only a one period lag in setting price contracts, then spot exchange rates do not overshoot and nominal interest rates do not react.[7]

When the capital gains term $i_t - E_t i_{t+1}$ is absent from the money demand equation ⟨1⟩, *i.e.*, when the parameter b is set to zero, the qualitative nature of the above predictions does not change. The only exception is the one-period interest rate, i_t, which does not change after the announcement. Its corresponding unobserved real interest rate, r_t, does change, however, by an amount equal to $(1-\theta)c(m_t - E_{t'} m_t)$.

II.B. The Expected Inflation Effect

The Expected Inflation effect arises in the special case when the only shocks to the money supply process are of the v_t type. In this case $g_t - E_{t'} g_t = m_t - E_{t'} m_t$, and from equations ⟨13⟩–⟨15⟩ we get:

⟨17b⟩ $$De_t = [(a+b)^{-2}(a+2b)(a+b+\theta)(a+\theta) - (a+b)^{-1} b(a+\theta+1)] \times (m_t - E_{t'} m_t)$$

⟨18b⟩ $$DE_t e_{t+1} = (a+b)^{-1}(a+b+\theta)(a+\theta)(m_t - E_{t'} m_t)$$

⟨19b⟩ $$DE_t e_{t+n} = (n+a+\theta-1)(m_t - E_{t'} m_t); \qquad n = 2, 3, \ldots$$

A positive surprise about m_t signals a higher rate of growth of the money supply and a higher future rate of inflation. This leads to an expected depreciation of the dollar in both the short and the long run, which is contrary to the empirical evidence.[8]

From equations ⟨17b⟩–⟨19b⟩, ⟨4⟩ and ⟨16⟩ the change in interest rates after the announcement of m_t is predicted as follows:

$$\langle 20b\rangle \qquad Di_t = b(a+b)^{-1}[1-(a+b)^{-1}(a+\theta)\theta](m_t - E_{t'}m_t)$$

$$\langle 21b\rangle \qquad Di_{t+1} = [1-(a+b)^{-1}(a+\theta)\theta](m_t - E_{t'}m_t)$$

$$\langle 22b\rangle \qquad Di_{t+n} = 1(m_t - E_{t'}m_t); \qquad n = 2, 3, \ldots$$

$$\langle 23b\rangle \qquad Di_t^{(n)} = (1-k/n)(m_t - E_{t'}m_t); \qquad n = 2, 3, \ldots$$

$$k = (a+b)^{-2}[\theta^2(a+2b)+(\theta+1)a(a+b)] > 0.$$

As long as $b > \theta$, the very short-term interest rates react positively to the announcement of M1. Notice that the Fisher effect takes hold after two periods when prices become perfectly flexible: Future expected short-term interest rates change by an amount equal to the revision in the expected rate of inflation, $(m_t - E_{t'}m_t)$. As the time to maturity increases, long-term interest rates also change by an amount equal to the revision in the expected rate of inflation: as $n \to \infty$, $Di_t^{(n)} \to (m_t - E_{t'}m_t)$. This is consistent with the strong reaction of long-term interest rates to the announcement of M1 and contrasts sharply with the zero reaction predicted by the Expected Liquidity hypothesis.

When the parameter b of equation ⟨1⟩ is set to zero the qualitative nature of the conclusions does not change. As in the case of the expected liquidity effect, the one-period interest rate, i_t, is an exception because it does not change after the announcement. Its corresponding real interest rate, r_t, does change, however, by an amount equal to $-a^{-1}(1-\theta)(a+\theta)^2(m_t - E_{t'}m_t)$. Notice that contrary to the case of the expected liquidity effect, the real one period interest rate reacts negatively. Also the reaction of $E_t i_{t+1}$ is positive as long as $a > (a+\theta)\theta$.

II.C. The General Case

When the money supply process is a two-part process, market participants cannot distinguish the two types of money supply shocks even after the announcement of m_t. If they follow the Bayesian rules of inference, then when m_t is announced, they revise their expectations of the underlying shocks s_t and v_t according to:

$$\langle 24\rangle \quad E_t s_t - E_{t'}s_t = w_{1t}(m_t - E_{t'}m_t); \qquad w_{1t} = \mathrm{Cov}(s_t, z_t|I_{t'})/\mathrm{Var}(z_t|I_{t'})$$

$$\langle 25\rangle \quad E_t v_t - E_{t'}v_t = w_{2t}(m_t - E_{t'}m_t); \qquad w_{2t} = \mathrm{Cov}(v_t, z_t|I_{t'})/\mathrm{Var}(z_t|I_{t'})$$

where $z_t = m_t - m_{t-1}$. The weights w_{1t} and w_{2t} are, in general, time varying as market participants form new posterior estimates of the conditional covariances and variances when new information comes in the market.[9] When the conditional covariance between s_t and z_t is high, markets attribute most of the surprise about m_t to the s_t type of shocks; although they also attribute part of the surprise about m_t to the v_t type of shocks and revise their inflationary expectations, the latter revision is minor.

The market reactions to the announcement of m_t are weighted averages of the reactions shown in subsections II.A and II.B. When the weight w_{1t} is relatively high the Expected Liquidity effect dominates the short-run market reactions. This implies that the dollar appreciates (depreciates) after an announced unanticipated increase (decrease) in m_t:

$$\langle 26\rangle \qquad De_t = -[w_{1t}l_1 + w_{2t}l_2](m_t - E_{t'}m_t);$$
$$l_1 = 1 + (a+b)^{-2}(a+2b)\theta > 0$$
$$l_2 = (a+b)^{-1}b(1+a+\theta) - (a+2b)^{-2}(a+2b)(a+b+\theta)(a+\theta).$$

Clearly, for large enough w_{1t} (or small enough w_{2t}) the term in the brackets is always positive. That is, when $w_{1t} > -(l_2/l_1)w_{2t}$ exchange rates are predicted to move in the direction consistent with the empirical evidence.

Both short-term and long-term interest rates are predicted to rise after a positive unanticipated increase in m_t, which is also consistent with the evidence.[10] The reaction of short-term interest rates is primarily due to an expected liquidity effect. But the influence of the expected liquidity effect declines as the time to maturity increases. Long-term interest rates react solely because of the presence of an inflation premium effect:

$$\langle 27\rangle \qquad \text{as } n \to \infty, \qquad Di_t^{(n)} \to w_{2t}(m_t - E_{t'}m_t).$$

Market participants revise their inflationary expectations proportionately to the weight they place on the occurrence of persistent shocks on the growth rate of the money supply, w_{2t}. So as long as w_{2t} is positive, no matter how small it may be, long-term interest rates will react positively to the announcement of m_t.

Equations ⟨26⟩ and ⟨27⟩ show that the observed reactions of spot exchange rates and long-term interest rates are not necessarily contradictory. According to the model, they coexist in the plausible case when markets perceive that most of the unexpected variation in the growth rate of the money supply is of temporary nature. This is a case where markets do trust the Fed's pre-announced money growth targets, yet they do not place full faith in them.

The model also predicts that the expected exchange rates of the distant future move in the opposite direction from spot exchange rates. From equations ⟨19a⟩, ⟨19b⟩, ⟨24⟩, and ⟨25⟩ we get:

$$\langle 28\rangle \qquad De_{t+n} = [-cw_{1t} + (n+a+\theta-1)w_{2t}](m_t - E_{t'}m_t).$$

For $n > 1 - a - \theta + c(w_{1t}/w_{2t})$, the reaction coefficient is unambiguously positive no matter how small w_{2t}, the weight placed on the expected inflation effect, may be. This prediction is supported by the empirical evidence reported in Hardouvelis (1984a).

II.D. Changing Market Responses Across Time

It is important to stress that the market reactions are not necessarily equilibrium reactions, in the sense that markets have discovered the true stochastic process underlying money supply. For this to occur two major requirements have to be satisfied. First, some time has to pass before market participants gather enough observations so that the time varying weights w_{1t} and w_{2t} converge to equilibrium weights. That is, enough data have to be observed before the original prior beliefs of market participants stop carrying any weight in the market reactions. Second, as emphasized by Craine and Hardouvelis (1983) in a more general context, the parameters of the stochastic process describing the money supply itself have to be stable. That is, the Fed has to follow the same policy rule for markets to be able to discover that rule. This has not been true in recent years. The Humphrey–Hawkins Act of 1978, the October 1979 monetarist experiment, and the October 1982 de-emphasis of M1 are recent examples of policy regime changes. Loeys (1985) has found that in these instances and many others the reactions of short- and long-term interest rates have indeed changed. Hardouvelis (1984a,b) and Cornell (1983b) have also emphasized that the exchange-rate reactions differ across time, particularly before and after October 1979. Prior to October 1979 the expected inflation effect dominates slightly the exchange-rate reactions.

The changing market responses to money announcements across time implies that one cannot examine the actual evolution of the money supply process and perform formal tests of the combination hypothesis. Since markets are not necessarily in a rational expectations equilibrium, tests of this sort are not very informative.

II.E. Responses in Other Markets

The combination hypothesis advanced in the present paper can also be used to explain the responses in other markets. Frankel and Hardouvelis (1985), for example, argue that the combination hypothesis is consistent with the commodity price reactions since 1977. They find that after October 1979 there was a dramatic change in the nature of commodity price responses. As in the case of exchange-rate reactions, prior to October 1979 the expected inflation effect was dominating the commodity price reactions, but after October 1979 the expected liquidity effect became the dominant effect. Hardouvelis (1985) finds evidence that the market responses to the PPI announcement may be the result of both an expected liquidity and an expected inflation effect operating at the same time.

III. Conclusion

The simultaneous increase in long-term interest rates and in the value of the dollar after an announced larger than anticipated stock of money are not contradictory pieces of evidence. The dollar appreciates because real short-term interest rates increase. Long-term interest rates increase because the inflation premium embodied in long-run forward interest rates increases. Both can take place when markets do trust the Fed's pre-announced annual money growth targets, yet they also retain a fear that the targets may be abandoned in the future.

The paper provides a model which formalizes the above argument. When M1 is announced, market participants do not know whether the unanticipated change in M1 will be counteracted or accommodated. Thus they react in a weighted average fashion with weights that reflect their respective subjective probabilities. When accommodation is thought to have a smaller chance, the observed reaction of spot exchange rates and long-run forward interest rates is a natural outcome. The response coefficients are, in general, time varying because market participants continuously revise their subjective probabilities when new information arrives in the market.

Notes

1. Engel (1981) mentions this as a theoretical possibility.
2. An alternative rule which is also based on microeconomic foundations is that of Mussa (1981): $P_{t+1} - P_t = E_t e_{t+1} - e_t + \theta(e_t - P_t)$. Adopting this rule results in a third order difference equation and the analytical solution is very complex and lacks intuition. This rule was used in Engel and Frankel (1984), and in a previous version of the present model in Hardouvelis (1982) where the parameter b was, however, set to zero.
3. It is possible to add a constant risk premium to equation ⟨4⟩ without altering the results because the announcement of M1 will not affect it.
4. As in the case of the open (uncovered) interest parity condition, the assumption that the Expectations theory of the term structure holds can be relaxed by adding a constant risk premium to long-term interest rates. This will not affect the results because the risk premium will not change after the announcement of M1.
5. M1 is actually announced with an eight day lag. This has no bearing on the propositions derived from the model.
6. The announcement of m_t affects the current demand for money because of the change in $E_t i_{t+1}$. Since the money supply does not change and since the price p_t and the money demand error term d_t are predetermined, the one period interest rate i_t changes to equate money demand with money supply. From equation ⟨1⟩ we can deduce that $Di_t = b(a+b)^{-1} DE_t i_{t+1}$, where D is the difference operator at the instant of the announcement.
7. In real life price contracts are set for much longer periods of time than what the model assumes. Therefore, the effect of rigid prices on the market reactions is stronger than what is predicted by the model. In Hardouvelis (1982), Mussa's price rule was adopted and the liquidity effect was stronger and lasted longer, declining slowly with time.
8. A sufficient condition for De_t to react positively is $a+b > b/a$. This condition is always satisfied when $b=0$.
9. In equilibrium, w_{1t} and w_{2t} converge to constant weights. See Mussa (1975) for a description of the equilibrium expressions for w_{1t} and w_{2t}.
10. Recall that for the very short-term interest rates the Expected Inflation hypothesis predicts an ambiguous reaction sign. But for large w_{1t} (or small w_{2t}) the ambiguity evaporates as the Expected Liquidity effect dominates the reaction of short-term interest rates. More precisely, the condition is: $w_{1t} > (c\theta)^{-1}[\theta(a+\theta) - a - b]w_{2t}$. This condition is always satisfied when, for example, $b > \theta$.

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