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Effects of Monetary Disturbances on Exchange Rates, Inflation and Interest Rates

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It has long been recognized that inflation is primarily a monetary phenomenon. However, some important implications of that relationship have become widely recognized only in recent years. We now realize, for example, that the link between the quantity of money and the price of goods also has implications for the value of financial assets—and further, that the effects of monetary disturbances on the prices of goods and assets have implications for international currency values in the foreign-exchange market.

The purpose of this article is to shed additional light on the relationship between a monetary disturbance and exchange rates by investigating the link through the goods and asset markets. Most analysts agree that the fundamental influence on the exchange rate is the need to maintain "purchasing power parity"—that is, parity of national price levels between countries. Because these national price levels change slowly over time, it had been assumed that the exchange rate would also change slowly over time. This has not occurred; since the move to flexible exchange rates in 1973, exchange rates have showed much greater variance than the underlying price changes.

This phenomenon has called into question the validity of the purchasing-power-parity approach to exchange-rate determination, at least in the short run. Analysts thus have developed a series of alternative models to explain short-run exchange-rate movements on the basis of factors other than purchasing power parity.[1]

This article presents one such model—one which links monetary disturbances to short-run adjustments in the bond market. In Section I, we present the long-run equilibrium effects of a monetary disturbance on inflation rates, interest rates, and exchange rates. We note there that the exchange rate in the long run is determined solely by purchasing-power-parity considerations, while long-run interest-rate differentials across countries reflect differences in inflation expectations. In Section II, we concentrate on short-run movements in the system. In this section, we question the standard assumption of continuous money-market equilibrium, and demonstrate that short-term exchange-rate movements depend on the short-run response of interest rates to a monetary disturbance. For example, a monetary disturbance can affect interest rates in two opposite ways, because it can have both a liquidity effect and an inflation-expectations effect. The adjustment path of the exchange rate toward long-run purchasing-power parity will depend on the relative magnitude of those two opposing influences. We note that profit opportunities in the bond market can induce short-term capital flows, which cause the exchange rate to move more than it would under conditions of short-run purchasing-power parity.

Section III translates the propositions of Sections I and II into testable hypotheses, and Section IV presents the evidence which tests

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these theoretical conjectures. To test the model, we utilize 4 sets of equations, each of which compares the U.S. bilaterally with five other major countries. The results suggest that in four of those countries (Germany, Italy, Japan, and Switzerland), the exchange rate changes more rapidly than the ratio of national price levels in response to a monetary disturbance, while in the fifth country (France), the adjustments occur at about the same speed. The results also suggest that for only one country (Switzerland), the exchange rate tends temporarily to overshoot its long-run value (the value consistent with long-run purchasing-power parity) following a monetary disturbance.

I. Theoretical Framework (Long Run)

The monetary approach to exchange-rate determination provides a conceptual basis for simultaneously analyzing the interactions among the major markets of the economy. We can begin with the determination of the long-run equilibrium price level. (All variables, except interest rates, are to be interpreted in log form.)

Home-country price level:

$$P = M - m^d \equiv ME \quad (1)$$

Foreign-country price level:

$$P^* = M^* - m^{d*} \equiv ME^* \quad (2)$$

where:

*denotes foreign country

P = log of price level

M = log of nominal money supply

m^d = log of real money demand (assumed to depend on the nominal interest rate and real permanent income)

ME = log of "excess money" (defined as the difference between the log of *nominal* money supply and the log of *real* money demand)

Equations 1 and 2 specify that, in the long run, the price level in each country is equal to that country's excess supply of money. These equations are based on the notion of long-run equality between real money supply and real money demand. They tell us that a rise in the level of the nominal money supply will, given constant real money demand, be matched by a proportional rise in the price level.

We assume here that only the domestic central bank can supply money and that only residents of a country will demand money denominated in that currency. This money-demand assumption is based on the unique role of the national money stock as a means of payment. One cannot purchase goods in one country with the currency of another country. There is a strong preferred habitat in the demand for money which is not necessarily observed in the demand for goods or non-money assets. An excess supply of money in one country cannot be used directly to satisfy the excess demand for money in another country, i.e. there is no currency substitution.[2] However, an increase in excess money in one country will induce an excess demand for goods and financial assets in that country which, in turn, can affect the goods and assets markets in another country. The exchange rate acts as a conduit to link the goods and asset markets of the two separate countries.

The next step in the analysis involves the formation of inflation expectations. We assume that price expectations are formed rationally. The rational-expectations view of market behavior says that market participants form forecasts of future events based on the relevant economic model and all available information. We can therefore use price equations 1 and 2 to generate the following price-expectation equations:

$$p^e = ME^e \quad (3)$$

or in change form

$$\Delta p^e = \Delta ME^e \quad (4)$$

where 3) and 4) are long-run equilibrium conditions which hold for each country. Superscript e denotes expectations, and ΔP and ΔME

refer to the first differences of logs of the price level and excess money, respectively. Equation 3 says that if excess money determines the actual price level, then expected excess money will determine the expected price level. Similarly, current long-run inflation expectations in each country are determined by long-run expected excess-money growth.

Our next equations deal with the determination of the long-term nominal interest rate. We assume that the real interest rate—that is, the nominal rate minus the expected inflation rate—in the long run will be independent of monetary factors. This assumption is based on the presumed existence of "real assets", whose nominal yields automatically adjust by the same amount as the inflation rate. The inflation-adjusted yield on these "real assets" is therefore determined solely by technological factors, which are presumably independent of monetary factors. Because of the possibility of substitution over the long run between financial assets and these real assets, nominal rates on financial assets also will fully incorporate any change in long-run inflation expectations. Combining this concept with equation 4, we arrive at the following equation:

$$R = \Delta P^e + r = \Delta ME^e + r \qquad (5)$$

where:

R = long-term market interest rate
ΔP^e = expected long-run inflation rate
ΔME^e = expected excess money-growth rate
r = real interest rate.

Our next equations explain the equilibrium exchange rate. Equation 6 expresses the purchasing-power-parity (PPP) condition which equates the exchange rate (S) to the difference of the log of the price levels in each country (P*-P), adjusted for terms of trade (T).[3]

$$S = P^* - P + T = ME^* - ME + T \qquad (6)$$

and

$$\Delta S^e = \Delta P^{*e} - \Delta P^e = \Delta ME^{*e} - \Delta ME^e \qquad (7)$$

Equation 7 assumes that expected changes in terms of trade (ΔT^e) are zero. As these changes generally take the form of real shocks, it seems reasonable to assume that expected changes over time are zero. Equation 6 tells us that the equilibrium bilateral exchange rate is a function of the ratio of excess money supplies of the two countries. Equation 7 tells us that the long-run expected change in the exchange rate depends on the long-run expected growth in the excess money supply of each country.

Because of the possibility of substitution between real assets of different countries and because of long run PPP, we can also assume that over the long run, real interest-rate parity will hold:[4]

$$r = r^* \qquad (8)$$

From equations 5 through 8 we can derive the nominal interest-rate parity condition:[5]

$$R = R^* - \Delta S^e \qquad (9)$$

This equation tells us that the domestic nominal interest rate should be equal to the foreign nominal interest rate minus the expected annual rate of appreciation of the domestic currency over the term of the asset.

All of these equilibrium relationships can be expected to hold over the long run, with certain short-run deviations. Also, all of the equations are valid under both fixed- and flexible-rate regimes, although with different directions of causality under the two structures.[6] In this paper we deal only with adjustments under a flexible-rate regime. The general equilibrium nature of the model can best be illustrated by an analysis of the long-run effects of some monetary disturbances, which then provides a point of reference for an analysis of short-run adjustments.

Consider first the long-run effects of a one-time contemporaneous increase in the level of a country's money stock, with no change in its expected future growth. The resulting increase in the supply of money relative to the demand for money will be matched by an equal excess demand for the sum of goods and non-monetary assets. Equilibrium will be restored in this case via a price adjustment, i.e. a rise in the domestic price level and a depreciation of the exchange rate. Equations 1 and 2 determine the home and foreign price levels, and equation 3 determines the exchange rate. The neutrality of money and PPP conditions requires that the changes in the price level and the exchange rate be proportional to the initial increase in the money stock. The rise in the price level will reduce the real money supply to its initial level, restoring equilibrium in the money market, and the depreciation of the exchange rate will maintain the purchasing-power-parity condition. Interest rates will not be affected by this one-time change in money, because there will be no change in its expected future growth rate, and thus no change in inflation expectations.

Next consider the long-run effects under a flexible-rate regime of a second type of monetary disturbance—a permanent increase in the growth rate of the domestic money supply. Again, equilibrium will be restored via a price adjustment. An expected higher money growth rate leads to a higher expected inflation rate, which means a comparable increase in the long-term interest rate; the interest-rate differential between two countries will therefore just equal the expected inflation differential. In a steady-state condition, the money supply, the price level, and the exchange rate will all change at the same rate (equal to the expected rate), and the level of the long-term interest rate will be permanently higher. There will be no incentive to switch between securities of different countries, because higher domestic interest rates will fully compensate holders of domestic financial assets for the expected depreciation of the currency.

The usefulness of the long-run model depends on one key empirical regularity—purchasing-power-parity, or the equality between bilateral exchange rates and the ratio of national price levels. In the long run, a close association of this type has been apparent for the United States with respect to five other countries: France, Germany, Italy, Japan, and Switzerland (Chart 1). However, for reasons discussed in the next section the relationship is not particularly close in the short run.[7]

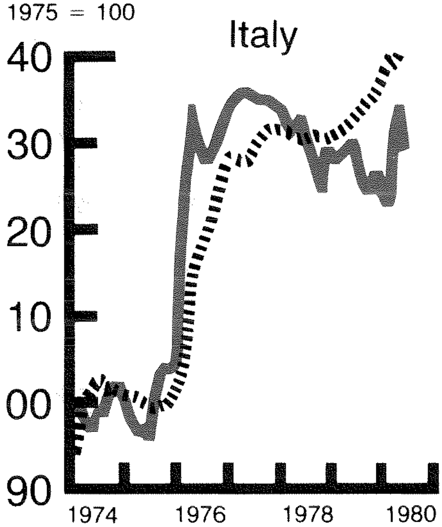
II. Theoretical Framework (Short Run Adjustments)

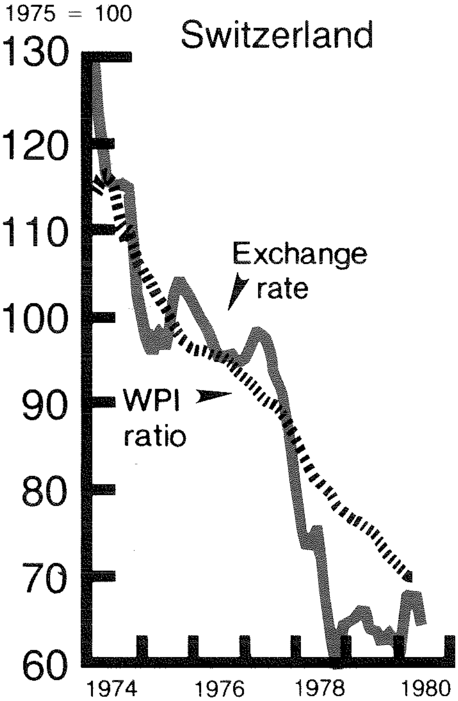
Our analysis of the nature of the long-run equilibrium does not describe the mechanism by which equilibrium is achieved, nor does it describe the movements of the economic variables between equilibria. The short-run movements of the system depend on assumptions about the nature of the adjustment process in different markets. As seen below, real interest-rate parity (equation 8) need not hold in the short run, but nominal interest-rate parity (equation 9) is a short-run condition which must hold at all times. On the basis of these relationships—along with assumptions about adjustment in the goods, financial assets, and money markets—we can determine the short-run movements of the exchange rate in response to a monetary disturbance. The link between the long run and short run, for the purpose of analyzing exchange-rate movements, can be operationally defined by the bond-market yield curve, which describes the yield on bonds of different terms to maturity. The underlying economic forces are fundamentally determined by liquidity considerations and market expectations about future money growth and inflation. To understand why exchange rates adjust differently in the short run than in the long run, we must understand why the yield curve varies in response to the forces noted here.

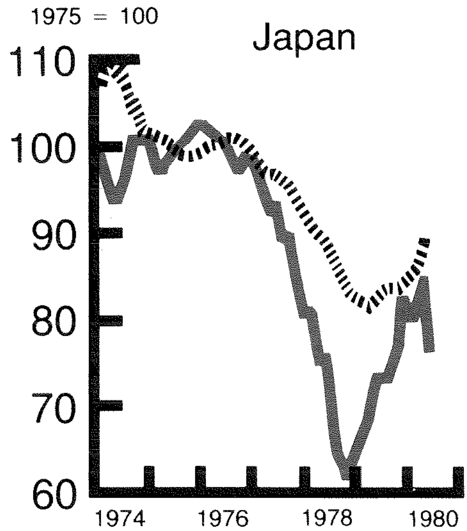
If the yield curve remains unchanged in response to a monetary change, then short-run and long-run exchange-rate adjustments would be indistinguishable. A change in excess money would lead to an immediate exchange-rate response, bringing the exchange rate immediately to its long-run equilibrium value—that value consistent with long-run purchasing-power parity. This response occurs even though adjustment in the goods market is not instantaneous, i.e., is lagged over a few years. If the yield curve changes, however, then

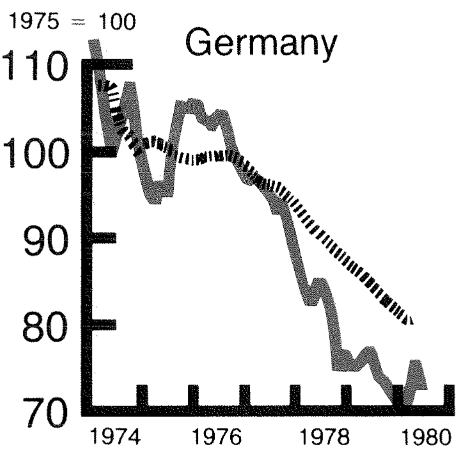
Chart 1

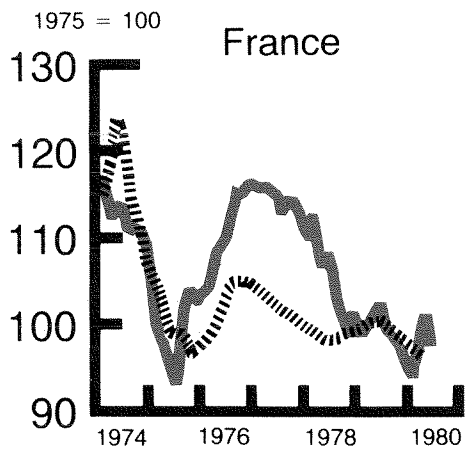
A Comparison of Exchange Rates and Prices











short-run and long-run exchange-rate adjustments would be different, as is explained in detail below.

To analyze the short-run movements of the system in response to a change in money supply, we must 1) distinguish between different types of changes in the money supply, and 2) make assumptions (based on observations) about the nature of the adjustment process in certain markets.

Money-supply Changes

There are two types of distinctions which should be made regarding money supply changes: a) permanent/transitory, and b) expected/ unexpected (Figure 1). The permanent (as opposed to transitory) change in the level of the money stock is that part which it is believed will not be reversed in the short run, i.e., the part that will result in a permanent change in the level of the money supply. Only the permanent part of the money-supply change is generally believed to affect economic behavior. This occurs because transactions are not costless, and if the public believes that money supply changes will shortly be reversed, they will avoid taking action and will temporarily absorb these balances in their holdings of money.[8] The expected money-supply change is the part which market participants anticipated in advance (by the length of the planning horizon), while the unexpected money-supply change is the difference between the actual and expected money-supply change. Thus, if individuals two years ago expected the money stock to rise by 5 percent this year, when in fact it rose by 15 percent, then 5 percent would represent the expected part, and 10 percent the unexpected part, of the change.

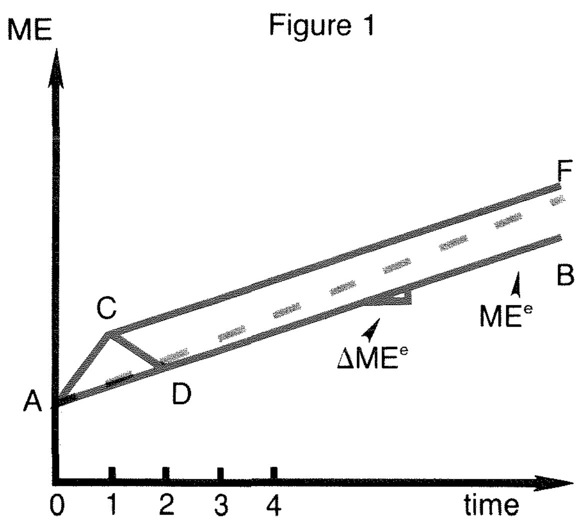
The line AB in Figure 1 is the expected path of excess money over some relevant planning horizon. ME^e is the level of excess money which is currently expected to exist at various points in the future. $\Delta(ME)^e$ is the expected growth in excess money. A movement from A to C represents a deviation of excess money from its expected growth path. Following such a move, excess money could proceed along either of two possible paths. 1) Actual excess money could move to D in the next time period, at which point it would be back on the previous expected path (AB). In this case, the deviation is only transitory, and the monetary disturbance would have no economic consequences for prices, interest rates or exchange rates. 2) Alternatively, actual excess money could proceed towards point F in succeeding time periods. This *permanent* change in the level of excess money, which was unexpected at the beginning of the planning period, could have definite effects on the economy. The price level would eventually be higher because point F is higher than point B. Also, short-run inflation expectations would be higher because the slope AF is greater than slope AB. However, long-run inflation expectations would remain unchanged. Such expectations are based on long-run excess money-growth expectations. With line CF extended into the "long run" (e.g., to point H), the slope of AH (long-run excess money growth) approaches the slope of AB (the previously expected long-run money growth). There would therefore be no change in expected long-run excess money growth or in long-run inflation expectations.

We assume that if actual money changes are expected and seen to be permanent (along line AB), there will be no lag between excess money and prices. In this specific case, contracts and other impediments to adjustment would be arranged to ensure that price changes occur when the money supply is expected to support the price change. Fully anticipated, permanent changes in the money supply thus lead to contemporaneous price increases, and the system therefore moves immediately to its new long-run equilibrium. In this case there are no short-run adjustments. In sum, because transitory money-supply changes have no effect on the economy, and because fully anticipated permanent changes result in an immediate move to the long-run equilibrium, we should concentrate on the results of a *permanent, unanticipated* change in the money stock (A-C-F). (To avoid awkward phrasing, the rest of the text will assume that all money changes are permanent, unless otherwise indicated.)

In this situation, the difference between the long run and the short run becomes important. In the goods market, prices will adjust only with a lag, and in the bond market there may be a shift in the term structure of interest rates (yield curve). These adjustment lags from an unanticipated money change could lead to short-run exchange-rate changes which are different from those resulting from an anticipated change in excess money—and which can cause purchasing-power parity not to hold in the short run. In the following discussion we will consider the different adjustment lags in the goods, money and bond markets, and further, consider their implications for exchange-rate adjustments.

Goods Market. The lags in the adjustment of goods prices in response to unanticipated money-supply changes have been well documented.[9] Two different types of lags can be differentiated. First, there is *recognition lag:* the time the market takes to recognize a change in the level of excess money and to differentiate between the permanent and the purely transitory part of that change. Given transaction and decision costs, individuals will delay changing their behavior until they are reasonably sure that a money change is permanent—that is, a move to F instead of to D in Figure 1. Secondly, there is *market-adjustment lag:* the time that goods-market prices take to adjust to recognized changes in excess money. Because of imperfect markets and information flows, there are lags between demand-and-supply shifts and changes in product prices.[10]

Figure 1



The existence of an organized secondary market in a product serves to eliminate the market-adjustment lag from the adjustment process.[11] These markets are organized so that changes in demand immediately become reflected in the price, i.e., the dealer or "auctioneer" moves the price immediately to equilibrate supply and demand, effectively eliminating any information problems. In addition, the factors which encourage the formation of organized markets also make these markets well suited for the activities of speculators and arbitrageurs. Once the recognition lag has passed, individuals realize that a price change is going to occur. Knowing this, market participants will buy or sell as soon as possible in anticipation of the price change, and this speculation causes the price change to occur right away. Because of these two factors, organized secondary markets do not exhibit a market-adjustment lag, but only a recognition lag, between the occurrence of a monetary disturbance and a resultant price change.[12] In contrast, products which are non-homogenous and/or expensive to store and transport, generally are not traded in organized secondary markets. As a consequence, we experience imperfect information flows, a lack of speculation and arbitrage, and therefore delays in price changes. Prices in most goods markets thus exhibit both recognition lags and market-adjustment lags in response to unanticipated money growth.

Money Market. To understand money-market adjustments, it is useful to review the money-price relationships of equations 1 and 2. These equations are based on an equality between the real supply and the real demand for money. In the present context, the relationship may be stated as follows:

$$m^s = m^d (y,R)$$

where m^s and m^d are the real supply and real demand for money respectively, and the real demand for money is a function of permanent real income (y) and the market interest rate (R). As seen above, an anticipated and permanent rise in the nominal supply of money will bring about a rise in goods prices contemporaneous with the rise in money supply, so that there will be no change in the real supply of money. In this case, there is no disturbance to the real demand for money—the only effect is a rise in prices. In contrast, an unanticipated but permanent rise in nominal money supply will lead to a lag in the adjustment of prices. In this case, the real supply of money will rise temporarily and require an adjustment in the real demand for money, thus affecting developments in the real economy, at least temporarily. Dornbusch (1976) in his article on exchange-rate overshooting, makes the standard assumption that the money market is always in equilibrium, i.e., that real money supply and real money demand are equal at all moments in time. If this is the case, then an increase in nominal money supply must be accompanied by an increase in the price level, an increase in real output, and/or a decrease in the nominal interest rate.[13] An increase in the price level would reduce real money supply, while an increase in real output or a fall in nominal interest rates would increase real money demand.

Given the slow adjustments of prices and output, continuous money-market equilibrium implies that the nominal interest rate must move immediately in order to equilibrate the real supply and real demand for money. Thus, a rise in the real money supply would lead to a fall in the market interest rate (liquidity effect). Once the goods-market adjustment is complete—initially through higher real income and eventually through higher prices—the interest rate in the bond market will return to its previous equilibrium value.

Our model does not differ in any fundamental way from this analysis, except that we allow for circumstances where the money market is in disequilibrium. Given goods-market disequilibrium, Walras' Law tells us that either the money market or the bond market, or both, must be out of equilibrium. It is reasonable to assume that the market interest rate moves to maintain equilibrium in the bond market, for which (unlike the money market) there are real-world primary and secondary markets. In that case, the goods market and the money market would be left out of equilibrium.[14] Such a result would occur if money were considered a "buffer stock", in much the same way that inventories may be out of equilibrium because of sudden shocks in either the supply or the demand side of the goods market.

Bond Market. As we have seen, the long-run effects of excess money on the bond market are purely expectational. Expected excess-money growth determines inflation expectations, and with the real interest rate given, determines the market interest rate. In the short run, an unanticipated increase in excess money can depress real market interest rates through a liquidity effect. But furthermore, it can tend to raise short-term interest rates through a rise in short-run inflation expectations. How is it possible to raise inflation expectations without a rise in long-run expected excess-money growth? Because a rise in excess money implies higher price levels once the goods-market adjustment is complete. This can raise short-run inflation expectations—the slope of AF is greater than the slope of AB—while leaving long-run inflation expectations unchanged.

A monetary disturbance can have offsetting liquidity and inflation-expectation effects on short-term interest rates. A rise in inflation expectations will shift the demand and supply of bonds so as to create upward pressure on the nominal interest rate. Thus, with interest rates determined by short-run equilibrium in the bond market, an unanticipated increase in excess money need not lead to a decline in market interest rates. Three conditions are possible, depending on the relative strengths of the two effects. 1) The liquidity effect is less than the short-run inflation expectation effect, pushing up short rates, leaving long rates unchanged, and thus causing a shift toward a more negative sloping yield curve. 2) The liquidity effect is greater than the expectation effect, causing a decline in short-run market rates and a shift toward a more positively sloping yield curve. 3) The liquidity effect is equal to the inflation-expectation effect, leaving market interest rates and thus the yield curve unchanged. Thus, short-run equilibrium in the bond market is consistent with different shifts in the slope of the yield curve, which means consistent with different exchange-rate adjustments.

Exchange Adjustments

Now that we have considered the short-run equilibrium conditions in domestic markets for money, goods and bonds, we can proceed to analyze the developments between countries which operate through foreign-exchange rates. The key assumption linking goods markets between countries is purchasing-power parity (equation 6), and the key assumption linking bond markets between countries is nominal interest-rate parity (equation 9). Because of the relatively long adjustment lags in the goods market, movements in the bond market will determine short-run movements in the exchange rate.

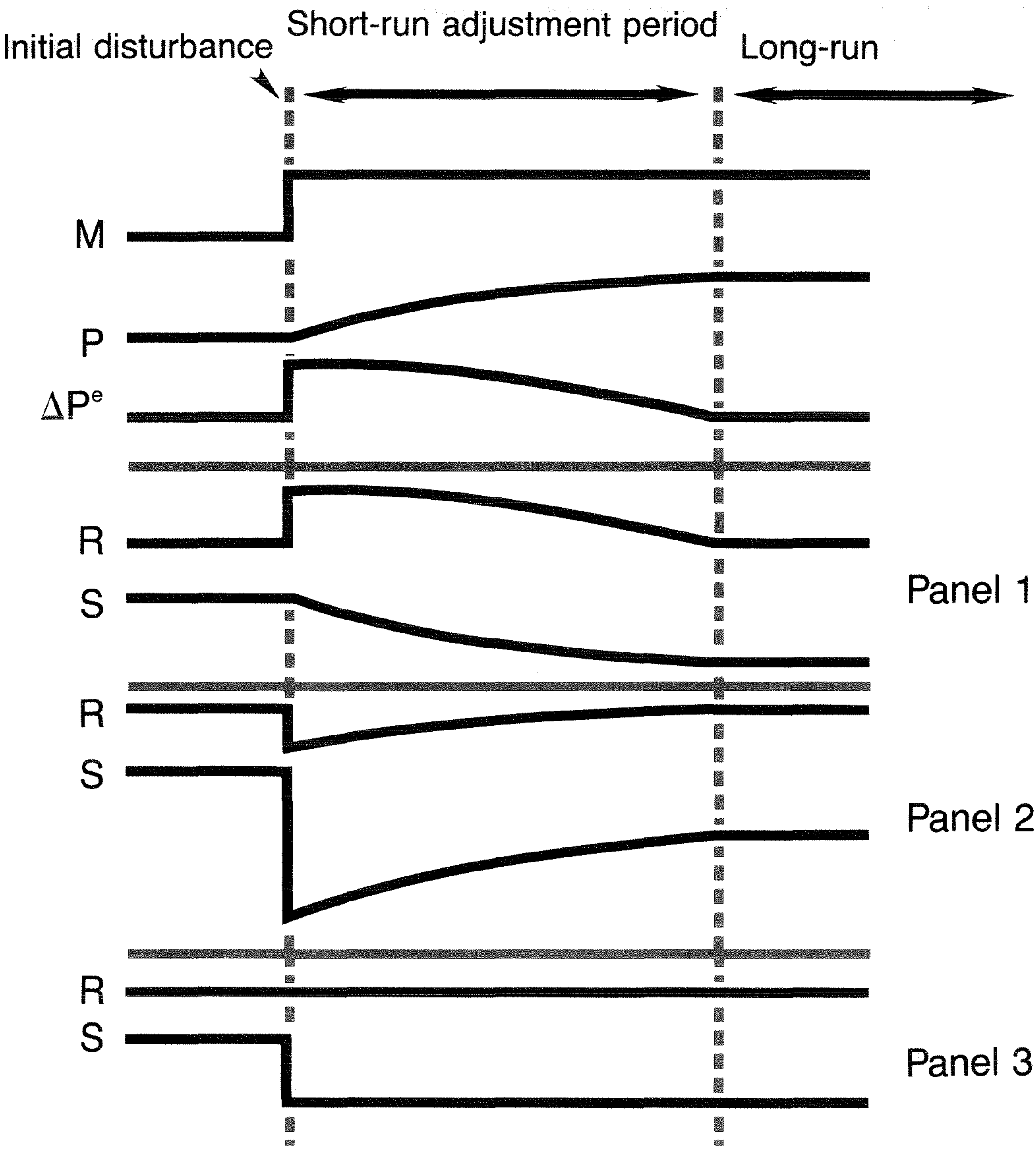
Under the assumption of perfect capital mobility, equation 9 represents a short-run condition which holds at all times.[15] The condition states that asset holders will be fully compensated for the expected depreciation of the currency in which their assets are denominated, i.e., that the nominal interest rate in one country will exceed the nominal interest rate of the foreign country by the amount of the expected depreciation of the domestic currency. If this condition did not hold, asset holders would be induced to shift out of the assets of one country into foreign assets in order to preserve the real purchasing power of their bonds. This would put immediate pressure on the exchange rate and/or the nominal interest rate, and drive the system back to the condition of nominal interest-rate parity. Thus, short-run profit possibilities create incipient capital flows which serve to maintain this condition. Short-run exchange-rate movements are therefore integrally related to movements in short-run interest rates.

Short-run movements of the exchange rate can be better understood by examining the effects of three different types of monetary changes.

The first situation involves a one-time *unanticipated but permanent* increase in the level of excess money (Figure 2). Assume that there is a 5-percent increase in domestic excess money (top line in Figure 2), that prices take one year to fully adjust to this disturbance, and that both the interest rate and expected inflation rate are one-year rates. In the long run, the effects of this disturbance will be a 5-percent rise in the domestic price level and a 5-percent fall in the exchange rate, with no change in the level of interest rates. In the short run, prices (P) would be expected to rise gradually over the course of a year and remain stable thereafter, at a level 5 percent higher than before the disturbance. Therefore, one-year inflation expectations (ΔP^e) will initially rise by 5 percent and then gradually return to their initial level. Long-run inflation expectations will be unchanged. The possible short-run adjustment paths are outlined in panels 1-3, corresponding to the three bond-market conditions cited above.

Panel 1). An extreme case where short-term interest rates increase to fully incorporate the expected price inflation, i.e. an initial 5-percentage-point rise in the short-term interest rate. This implies no liquidity-induced decline in the real rate of interest. (Recall that given slow adjustment of output, this rise in nominal rates also implies money-market disequilibrium). Under these circumstances the exchange rate should move toward its long-run value only gradually, at the same speed as the price level, i.e., the spot exchange rate moves so that purchasing-power parity is maintained at all times. The expected short-run depreciation of the exchange rate equals the expected short-run price increase (both 5 percent over one year). The compensating rise in short-term interest rates relative to long-term rates leads to a gradual depreciation of the currency.

Figure 2
Alternative Adjustments to a Monetary Disturbance



Note: For expositional purposes, we assume a one-year adjustment period between money and prices, and interpret the interest rate and expected inflation rate as one-year rates.

Panel 2). An opposite extreme where short-run market interest rates decline by the full amount necessary to maintain continuous money-market equilibrium. In this case, the short-run inflation-expectations effect is completely dominated by the liquidity effect. Not only are asset holders uncompensated for a decline in the real purchasing power of their security, they are also forced to accept a lower market-interest rate than they did before the unanticipated rise in excess money. This combination of circumstances will induce market participants to attempt to switch out of domestic assets into foreign assets, which will cause an immediate depreciation of currency by more than the 5-percent increase in excess money. Thus, given a decline in both real *and nominal* short-term interest rates, the exchange rate must depreciate to a level below its expected long-run value. This overshooting of the exchange rate (as described by Dornbusch), leads to an expected appreciation of the exchange rate over time. The expected appreciation of the domestic currency compensates for the lower domestic interest rate, and the interest-rate parity condition (equation 9) is maintained. In general, as long as the liquidity effect is greater than the inflation-expectation effect, there will be a shift toward a more positive-sloping yield curve as well as a temporary overshooting of the exchange rate.

Panel 3). An intermediate case, where the inflation-expectation effect exactly offsets the liquidity effect. In this panel, as in panel 2, asset holders are not compensated for the expected depreciation (a decline in the real purchasing power of their bonds), so that they attempt to shift out of domestic assets into foreign assets. This immediately depreciates the exchange rate. With no change occurring in the nominal interest-rate differential, the exchange rate must depreciate immediately by 5 percent to its long-run equilibrium value.

The long-run effects under each of the above assumptions are equivalent. However, the choice of assumption about the adjustment in the money and bond markets is critical in explaining short-run exchange-rate movements. Given our assumptions about goods prices and capital mobility, the existence of a liquidity effect ensures that the exchange rate will adjust more rapidly than prices in response to a monetary disturbance.

We can deal with the other types of monetary changes rather quickly. The second example of a monetary change involves a *fully anticipated and permanent* increase in the level of excess money movement along AB (in Figure 1). Because of the expected nature of this increase, inflation expectations and therefore nominal interest rates of all maturities have already adjusted—that is, domestic bond holders are being compensated for the higher (short-run) inflation. Both prices and the exchange rate should rise contemporaneously with the money increase, with no effect therefore on real money balances, the real interest rate, inflation expectations, or the market interest rate.

A final example involves an increase in the permanent growth rate of excess-money—that is, a change in the slope of the expected excess-money path. This represents a combination of two previous disturbances—an unanticipated increase in the level of money, followed by further anticipated increases, which are larger than previously anticipated. The short-term effects will therefore be similar to those in the first situation described above. The long-run effects will be similar to those in the second situation, although with increased long-run inflation expectations as well as short, reflecting the permanent alteration in the money-growth rate.[16] The higher level of inflation expectations will therefore lead to higher market-interest rates (long and short). The currency will depreciate gradually over time, coincident with and equal in size to the increase in the price level. But no profit opportunities will emerge in the bond market, because interest differentials will adjust to compensate fully for the expected inflation and for the exchange-rate depreciation.

The key, therefore, to understanding short-run movements in the exchange rate is to understand the effects of unanticipated excess money on the bond market. Theoretically, the effects are ambiguous in the short run, so that an appeal to the evidence is needed to resolve the question.

III. Testing the Hypothesis

We are now in a position to write the equations which will be estimated. These estimates will be used to test our theoretical conjectures and make inferences about both the long- and short-run adjustments of prices and exchange rates.

$$\Delta(P^* - P)_t = a_o' + \sum_{j=o}^{m} a_j \, \Delta\,(ME^* - ME)_{t-j} \quad (10)$$

$$\Delta S_t = b_o' + \sum_{j=0}^{n} b_j \, \Delta\,(ME^* - ME)_{t-j} \quad (11)$$

where m represents the length of the adjustment period between excess money and prices, and n represents the length of the adjustment period between excess money and exchange rates.

First we ask whether we can confirm the long-run relationship between excess money and prices, and between excess money and exchange rates. Further, we ask whether we can confirm that the long-run coefficients in the excess money/price relationships are equal to those in the excess money/exchange-rate relationships (i.e. $\Sigma b_j = \Sigma a_j$ for each country). For these tests, the distinction between expected and unexpected is not relevant, because the long-run effects of a money change on prices and exchange rates are the same in either case.

This is not so in the short run, however, because as we have seen, short-run adjustments of the system depend on whether the monetary change is expected or unexpected. In particular, if all money changes were expected, both prices and exchange rates should adjust contemporaneously with money, (i.e., m and n would equal zero). In contrast, if all money changes were unexpected, the money/price lag (m) should be long, while the money/exchange-rate lag (n) should depend on the short-term interest rate. In this connection, the existence of the liquidity effect on short-term interest rates ensures that adjustment will occur more quickly in exchange rates than in prices. This then raises the question whether or not excess money changes affect exchange rates more rapidly than they affect price-level ratios.

The unexpected/ expected distinction is easy to make conceptually, but difficult to make empirically.[17] Thus, we do not attempt to break down actual changes in excess money supply into expected and unexpected components. Money-supply changes over time undoubtedly have contained both of these components, so that we should see some combination of instantaneous and lagged adjustments in goods prices and foreign-exchange rates. All else equal, the greater the unexpected component relative to the expected component, the longer should be the lags between money and prices.[18]

Next, we estimate the long-run interest-differential equation. Differentials across countries (R_L^*-R_L) are a function of differences in long-run inflation expectations, and thus are due to differences in expected excess-money growth. The latter is determined not only by past excess-money growth, but also by other factors which market participants have found to be good indicators of future money growth, such as government budget deficits. Non-monetary factors are not directly included in our estimating equation, but any systematic movement in these variables could be captured through a Cochrane-Orcutt correction. Thus we obtain the following:

$$(R_L^* - R_L)_t = c_o' + \sum_{j=o}^{p} c_j \, \Delta\,(ME^* - ME)_{t-j} \quad (12)$$

The role of relative excess money growth in equation 12 is fundamentally different from that in equations 10 and 11. Equation 12, unlike equations 10 and 11, is designed to capture the effect of past actual money growth on expectations of money, providing evidence whether government authorities have changed the long-run target of future money growth. This is therefore a form of a central-bank reaction function. Past money growth's only role in this equation is as a generator of changes in inflation expectations. It has no role in either the state of the business cycle or the state of liquidity in the economy.

Next, we estimate short-run interest-rate differences across countries (R_s^*-R_s), which have a more complex relationship than long-run differences to current and past excess-money growth. This is because short rates are influenced by both liquidity and inflation expectations.

$$(R_s^* - R_s)_t = d_o' + \sum_{j=o}^{q} d_j \Delta(ME^* - ME)_{t-j} \quad (13)$$

The relationship between excess money and short-term interest-rate differentials may be positive if short-run inflation expectations dominate the relationship ($\Sigma d_j > 0$); it may be negative if liquidity effects dominate ($\Sigma d_j < 0$); and it may be approximately zero if the two effects offset one another. In addition, the sign of the d_js may vary between negative and positive if the liquidity effect dominates in the early months, and if the inflation-expectations effect dominates thereafter.

Although we cannot make any *a priori* statements about the relationship between short-term interest rate differentials and excess money growth differentials, we can say the following: a) If liquidity effects have any influence on short-term interest rates, then the exchange rate will adjust more rapidly than prices i.e., the difference between the money/price mean lags and the money/exchange rate mean lags should be relatively large. b) If liquidity effects initially dominate short-term interest-rate movements, then the exchange rate should overshoot the long-run equilibrium value, i.e., the short-run effects of excess money on the exchange rate should be greater than the long-run effects. c) If the liquidity effect has no influence on short-term interest rates and inflation expectations effects dominate initially, then the exchange rate should move more in line with prices—i.e., the difference between the money/price lags and the money/exchange rate lags should be relatively small.

IV. Empirical Estimation

To test the theory, we chose empirical measures which were as simple as possible, consistent with the variables in the theory. We measured the exchange rate in all cases as the monthly average of the bilateral rate between the U.S. dollar and the foreign currency (measured as foreign currency per dollar). For a money-supply measure, we chose the broad measure of money plus quasi-money from the IMF's **International Financial Statistics,** seasonally adjusted using an X-11 routine. The broad measure was used here because it was found to be generally superior to the narrow money-supply measure in earlier work of one of the authors (Keran, 1979), although both measures provided significant results with respect to exchange rates. For prices, we chose the wholesale-price indexes from **International Financial Statistics,** and again used an X-11 routine for seasonal adjustment. For interest rates, we chose 3-4 month representative money-market rates and long-term domestic government bond yields from Morgan Guaranty's **World Financial Markets.**

As a proxy for real money demand, we constructed a 36-month moving average of actual real money balances. This procedure is consistent with the assumption of noncontinuous equilibrium in the money market, and it reduces the complexity of both the model specifications and the statistical estimates. In using this proxy, we assume that purely transitory changes in real money demand have no effect on prices or exchange rates because they are expected to be reversed. We also assume that real money demand and real money supply are equal over the long run, which is defined as that time period in which prices adjust to a monetary disturbance. This period of adjustment may vary between countries, but presumably in each case is completed within three years—hence our choice of a 36-month moving average.[19]

All of the equations were estimated using the Almon polynominal distributed-lag (PDL) technique, which helps us distinguish between the permanent and transitory changes in excess money. Each equation was run a number of times, with different lag lengths ranging from 0 to 36 months and up to 4th degree polynomials. In all cases the far ends were constrained equal to zero. The "best" total number of lags and degree were chosen based on the criterion of lowest standard error of the regression. All of the equations were estimated with monthly data for the period January 1975-December 1978.[20]

We present the results from the "best" money/price equations for each country in Table 1, and the results from the "best" money/exchange-rate equations in Table 2. Tables 5 and 6 show the long- and short-term interest-rate results. In presenting the statistical results, we analyze a number of statistical measures which are briefly discussed in Appendix 1.

Money and Prices

Our results (Table 1) clearly support the theoretical belief in a significant relation between an increase in excess money and a rise in the price of goods, with the price lags reflecting a host of contractual, informational, and inventory adjustments. The t-statistics on the sum of lag coefficients are all a good deal greater than 2 (averaging 5.0), which confirms that the monetary variable is significant in explaining the inflation differential between countries.

The values of the Durbin-Watson statistics allow us to reject the possibility of autocorrelation in the errors. The lack of systematic errors in these equations is consistent with the notion that we have not left out any significant systematic explanatory variables. The total lag lengths ranged from 12 months for Italy to 36 months for France and Switzerland, with an average across countries of about 24 months. Lags longer than these only decreased the explanatory power of the equation. The time required for 75 percent of the total effect to occur ranged from 10 months for Italy to 30 1/2 months for France.

Money and Exchange Rates

As with money and prices, the evidence clearly supports a significant link between money and exchange rates (Table 2). The sum of the coefficients on the monetary variable are significant for all five bilateral exchange rates. While the $\bar{R}^2$s may seem low, all of the variables in the exchange-rate and price equations are measured in monthly percentage-change form, so that there is a great deal of unsystematic and random "noise" in the series

Table 1
Relationship of Changes in Wholesale Price Ratios and Excess Money, 1975–78

$$\Delta(P^* - P)_t = a_o' + \sum_{j=o}^{m} a_j \Delta (ME^* - ME)_{t-j}$$

Country	Total No. Lags	75% Effect Lag	Constant	Σ Lagged Coefficients	$\bar{R}^2$	S.E.R.	Rho	D.W.
France	36	30.5	−.0021 (−1.81)	3.74 (4.94)	.338	.0066	—	1.66
Germany	18	14.5	.0012 (1.10)	1.33 (4.12)	.263	.0037	—	1.67
Italy	12	10.0	−.0196 (−5.26)	3.07 (6.58)	.760	.0052	—	1.63
Japan	18	15.0	−.0031 (−5.26)	1.36 (6.64)	.511	.0039	—	1.71
Switzerland	36	30.0	.0005 (.22)	2.30 (3.30)	.183	.0048	—	1.82

t-statistics in parenthesis

which is not explained by the independent variable.[21]

Table 3 presents the sum of the lag coefficients for the price and exchange rate equations, the difference between the coefficients, and the t-statistics on each.[22] The exchange-rate coefficients are larger than the price coefficients for all countries except France, but in no case is there a statistically significant difference between the long-run price and exchange-rate coefficients. This is consistent with our theoretical argument that the long-run coefficients in the two sets of equations would be equal.

Next, consider the cumulative effects of excess-money changes on price ratios and exchange rates (Chart 2). This chart shows the total effect of an initial one percent change in excess money for any month in the adjustment period. Because the adjustment period is never longer than 36 months, the value plotted at lag 36 will be equal to the sum of the lag coefficients estimated in equations 10 and 11.

Exchange-rate overshooting, which occurs when excess money depresses short-term interest rates via the liquidity effect, should be indicated by a distributed lag in the exchange-rate equation consisting of positive coefficients followed by negative coefficients, with the sum equal to that in the price equation. Such overshooting was evident only in the case of Switzerland, for it was the only country showing significant negative coefficients in the lag patterns of the exchange-rate equations. This can be clearly seen in the pattern of exchange-rate lagged coefficients, where the cumulative effect first rises above the long-run value. The evidence in the short-term interest-rate equations is also consistent with this liquidity/overshooting explanation.

Table 3
Long-run Coefficients of Exchange Rate and Price Equations

Country	(1) Exchange Rate Equation	(2) Price Equation	(1)-(2) Difference
France	3.44 (2.94)	3.74 (4.94)	−.29 (−.27)
Germany	3.09 (2.37)	1.33 (4.12)	1.76 (1.33)
Italy	3.31 (3.15)	3.07 (6.58)	.24 (.22)
Japan	1.89 (2.79)	1.36 (6.64)	.53 (.82)
Switzerland	3.17 (2.97)	2.30 (3.30)	.87 (.76)

(t-statistics in parenthesis).

Table 2
Relationship of Changes in Exchange Rates and Excess Money, 1975–78

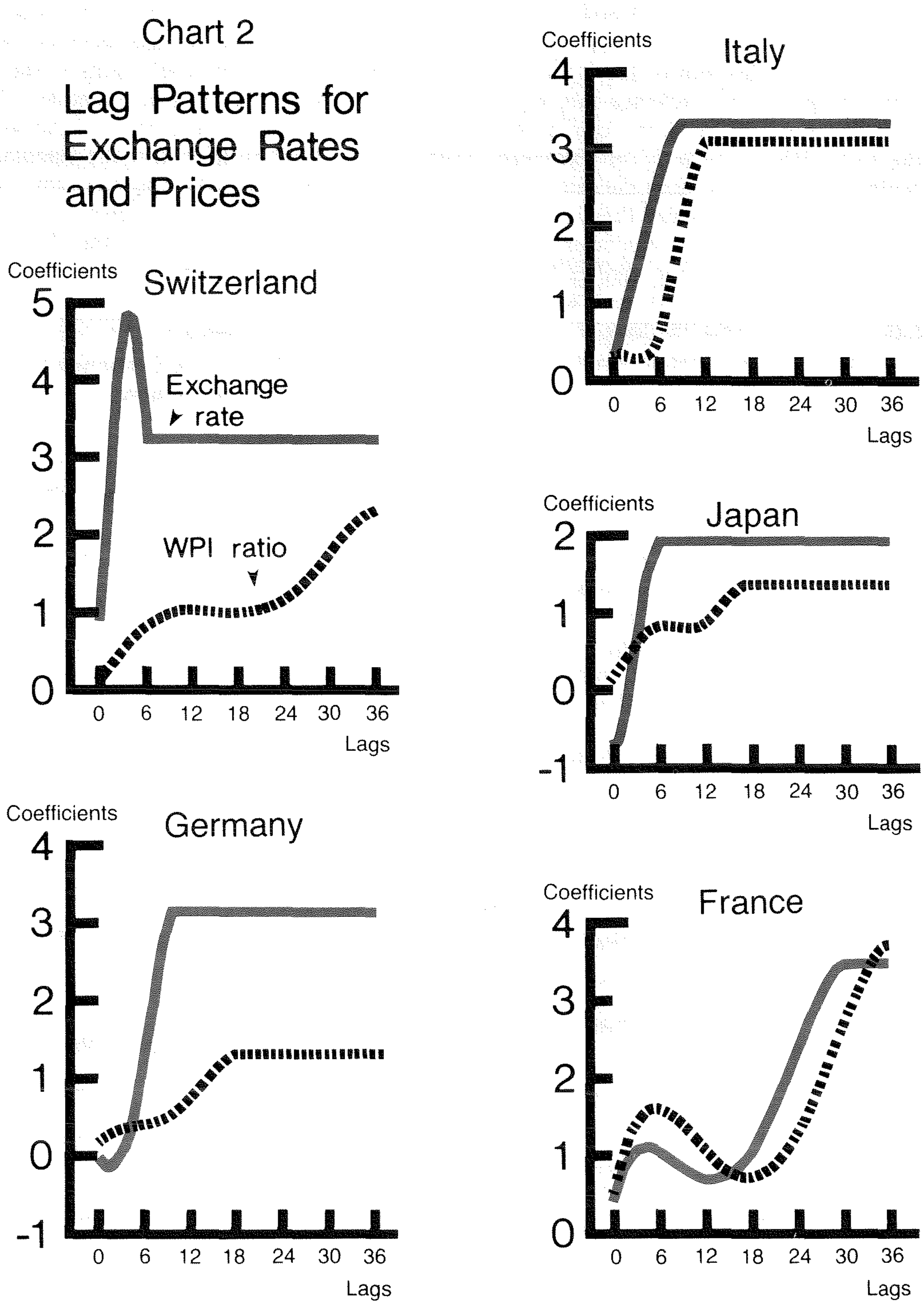
$$\Delta S_t = b_o' + \sum_{j=0}^{n} b_j \, \Delta \, (ME^* - ME)_{t-j}$$

Country	Total No. Lags	75% Effect Lag	Constant	Σ Lagged Coefficients	$\bar{R}^2$	S.E.R.	Rho	D.W.
France	30	25.0	−.0008 (−.25)	3.44 (2.94)	.124	.0184	—	2.00
Germany	9	7.5	.0044 (.91)	3.09 (2.37)	.118	.0196	—	1.88
Italy	9	5.75	−.0252 (−3.02)	3.31 (3.15)	.675	.0131	—	1.58
Japan	6	4.5	−.0037 (−2.37)	1.89 (2.79)	.168	.0204	—	1.67
Switzerland	6	1.0	.0057 (.98)	3.17 (2.97)	.335	.0229	—	1.50

t-statistics in parenthesis

Chart 2

Lag Patterns for Exchange Rates and Prices



*The coefficients charted above show the *cumulative* effects of a monetary disturbance on the exchange rate and the WPI ratio, and are derived by cumulatively adding the lag coefficients estimated in equations 10 and 11.

The exchange-rate equations are notable for the shortness of the lags between money and exchange rates (Table 4). For all countries except France, the total lag ranged between 3 and 9 months, and averaged about 7 months; for France, the lag was 30 months. Similarly, the 75-percent effect—the time required for 75 percent of the exchange-rate impact to occur—ranged below 8 months for all countries except France (25 months). We may conclude that money affects exchange rates more rapidly than it does prices, judging from the evidence that both the total and 75 percent-effect lags were substantially less in the exchange-rate equations than in the price equations. According to our theoretical model, these shorter lags are consistent with monetary disturbances resulting in changes in real interest rates (liquidity effects). We will see that the evidence from the short-term interest-rate equations is consistent with this theory.

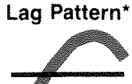
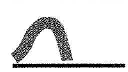
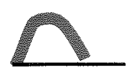
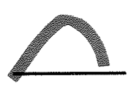
Our model is incomplete because it captures the real terms-of-trade effect on the exchange rate only in the constant term. Admittedly, this is unrealistic. For example, one of the authors (Keran, 1980) has shown that the yen/dollar

Table 4
Money-Exchange Rate and Money-Price Lags
(in months)

	Exchange Rate Equation		Price Equation		
Country	(1) Total Lag	(2) 75% Effect Lag	(3) Total Lag	(4) 75% Effect Lag	(4)-(2) Difference
France	30	25	36	30.5	5.5
Germany	9	7.5	18	14.5	7.0
Italy	9	5.75	12	10.0	4.25
Japan	6	4.5	18	15.0	10.5
Switzerland	6	1.0	36	30.0	29.0

Table 5
Relationship of Long-term Interest Differential and Changes in Excess Money, 1975–78**

$$(R_L^* - R_L)_t = c_o' + \sum_{j=o}^{p} c_j \, \Delta \, (ME^* - ME)_{t-j}$$

Country	Total No. Lags	Constant	Σ Lagged Coefficients	$\bar{R}^2$	S.E.R.	Rho	D.W.	Lag Pattern*
France	36	1.88 (14.88)	.07 (1.84)	.909	.2127	.71 (6.93)	2.05	
Germany	21	.06 (.15)	.45 (4.63)	.968	.2425	.88 (12.65)	2.26	
Italy	18	−1.83 (−2.04)	.52 (6.11)	.843	.5074	.59 (5.05)	1.89	
Japan	24	−0.50 (−3.07)	.29 (8.03)	.972	.2044	.82 (7.68)	2.48	
Switzerland	30	−2.88 (−5.93)	.38 (4.47)	.973	.2153	.89 (13.26)	2.61	

*Shaded areas indicate not significantly different from zero.
t-statistics in parenthesis
**In order to better interpret the coefficients of these equations, annualized percentage changes in excess money are used instead of the difference of logs.

exchange rate is significantly affected by the real price of oil. Real terms-of-trade factors are beyond the scope of this paper, but they still remain important.

Money and Long-Term Interest Rates

We obtain quite strong results from the equations estimating the relationship between long-term interest rates and the growth in excess money (Table 5). Relative to the U.S., all countries show a significant positive relationship between the level of the interest-rate differential and the growth rate in excess money.[23]

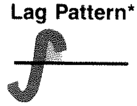
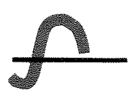
The link reflects the fact that changes in long-term interest rates are due primarily to changes in long-run inflation expectations, which in turn are based on expected future excess-money growth. Forecasts of future money growth often depend on the pattern and size of current and past money-growth rates. Therefore we obtain a significant statistical correlation between the level of the long-term interest differential and current and past growth rates of excess money. The t-statistics on the sum of lag coefficients ranged from just under 2 for France to more than 8 for Japan. Before adjustment for autocorrelation, the DW statistics were extremely low, suggesting that important variables were omitted from the equation—and indeed, we excluded from our equation other data which individuals might use to forecast future money growth and future inflation. Nonetheless, these results and the money-price results confirm the relationship between excess money-growth differentials on the one hand, and current and expected future inflation differentials on the other.

Money and Short-Term Interest Rates

Our empirical results reflect the ambiguity of our theoretical argument, that an increase in excess money can simultaneously have a liquidity effect which reduces short-term rates and an inflation expectations effect which increases short-term rates (Table 6). In the cases of France and Switzerland, the liquidity effects dominate initially; in the cases of Germany and Japan, the results are not significant, reflecting offsetting effects; and in the case of Italy, the inflation-expectation effect dominates initially. The evidence (except for France) also supports our theory that countries with the greatest liquidity effects would show the larg-

Table 6
Relationship of Short-term Interest Differential and Changes in Excess Money, 1975–78**

$$(R_s^* - R_s)_t = d_o' + \sum_{j=o}^{q} d_j \Delta(ME^* - ME)_{t-j}$$

Country	Total No. Lags	Constant	Σ Lagged Coefficients	R^2	S.E.R.	Rho	D.W.	Lag Pattern*
France	15	−.35 (−.16)	−0.13 (−.61)	.881	.7847	.95 (20.18)	1.98	
Germany	15	−692.82 (−1.43)	−.30 (−1.53)	.903	.5464	1.00 (381.63)	1.82	
Italy	21	−12.61 (−3.54)	1.87 (5.49)	.913	1.2385	.74 (7.73)	1.72	
Japan	24	−5.08 (−1.72)	.25 (1.22)	.958	.6729	.97 (28.35)	1.24	
Switzerland	24	−2.74 (−6.32)	.64 (7.32)	.894	.7270	.58 (4.90)	2.17	

*Shaded areas indicate not significantly different from zero.
t-statistics in parenthesis
**In order to better interpret the coefficients of these equations, annualized percentage changes in excess money are used instead of the difference of logs.

est differences between the lags in the price and exchange-rate equations, and that countries with large inflation-expectation effects would show the lags in the exchange rate closely corresponding with the lags in goods prices. With the exception of France, the evidence is consistent with this theory. Switzerland has a significant initial liquidity effect, overshooting in the exchange rate, and the largest difference between the price and exchange rate 75-percent-effect lags; Italy has a significant initial inflation-expectation effect and the smallest difference in these lags; and Germany and Japan have insignificant inflation-expectation and liquidity effects, with differences in these lags falling between those of Switzerland and Italy. Switzerland shows a significant initial liquidity effect which is accompanied by an overshooting of the exchange rate. France also shows a significant liquidity effect, but does not show a rapid adjustment of the exchange rate. This may perhaps be explained by France's pervasive system of capital controls.[24] Again, before adjustment for autocorrelation, the DW statistics were extremely low in these equations, indicating the probable omission of systematic explanatory variables.

V. Summary and Conclusions

It has long been believed and is now widely accepted that exchange rates in the long run will be determined by purchasing power parity. That is, the exchange rate will be largely determined by equilibrium conditions in the goods market. Because of the slow adjustment of this market to economic disturbances, it was generally assumed that the exchange rate would also adjust relatively slowly. In fact, however, variations in the exchange rate have been considerably greater than variations in prices across countries.

These facts have not shaken most analysts' views about the long run validity of purchasing-power parity. As Figure 1 indicates, exchange rates do, in fact, move in line with the ratio of national price levels over the long run. However, the relatively large short-run deviations from purchasing-power parity require an explanation. In analyzing short-run movements in exchange rates, most analysts focus on the role of interest-rate parity. Interest-rate differentials across countries can influence capital flows and thus exchange rates.

Research in this area has focused on the use of money-market equilibrium models for interest-rate determination (see, for example, Dornbusch 1976). Given lags in the adjustment of the goods market, an increase in the supply of money, in these models, will necessarily lead to a decrease in interest rates (so-called liquidity effect) and thus to a temporary decline of the exchange rate below its long-run equilibrium value. Later, as the goods market responds to this monetary disturbance, interest rates will gradually rise and the exchange rate will appreciate back to its long-run value. This temporary overshooting leads to greater variation in exchange rates than in the ratio of national price levels.

In this article, we evaluate the short-run relationship between interest rates and exchange rates. In our short-run model, interest rates are determined in the bond market, rather than in the money market. This circumstance permits a wider range of interest-rate responses to a monetary disturbance.

An increase in the money supply can have both a short-run liquidity effect and a short-run inflation-expectation effect (Figure 2). These effects have opposite implications for interest rates. 1) If the liquidity effect is dominant, then short-run interest rates will decline and there will be exchange-rate over-shooting. 2) If the inflation-expectation effect is dominant, then interest rates will rise and the exchange rate will move slowly to its long-run equilibrium value. 3) If the liquidity and inflation-expectation effects are equal, there will be no change in short-term interest rates and the exchange rate will move immediately to its long-run value.

A comparison of the U.S. experience, vis-a-vis five major industrial countries, shows that: 1) For all countries, there is a statistically significant relationship between the monetary disturbance on the one hand, and exchange rates and the ratio of national price levels on the other.

2) There is no statistically significant difference between the long-term effects of a monetary disturbance on the ratio of national price levels and on exchange rates.

3) The exchange rate responds on the average much more quickly than the ratio of national prices to a monetary disturbance.

4) In only one country (Switzerland), is there evidence of exchange-rate overshooting in the short run. In three countries (Germany, Japan, Italy), the exchange rate moves quickly to its equilibrium value without overshooting, and in one country (France), exchange-rate movements were roughly in line with price movements.

The analysis and research in this paper show that interest rates do, in fact, play an important role in short-run exchange-rate movements. However, it is the equilibrium conditions in the bond market (not the money market) which determine short-term interest rates and thus exchange rates. These interest-rate movements are the source of greater short-run variations in exchange rates than in the ratio of national price levels.

APPENDIX
Description of Statistics

t-statistic on the coefficients: The t-statistic, which is equal to the ratio of the coefficient to its estimated standard error, is a key determinant of the statistical significance of the independent variable in explaining movement of the dependent variable. In our equations, a t-statistic greater than about 2 in absolute value indicates that the corresponding coefficient is significantly different from zero at the 95-percent coefficient level. t-statistics are calculated on each lagged coefficient and also on the sum of all lagged coefficients. The t-statistic on the sum, which is reported in the tables, tells us whether or not the long-run effect of the independent variable is significant in explaining movement in the dependent variable.

Adjusted $R^2(\bar{R}^2)$: The $\bar{R}^2$ tells us how much of the variance in the dependent variable can be explained by the variance in the independent variables, after adjusting for the number of observations and the number of independent variables. The $\bar{R}^2$ can be a misleading measure of goodness of fit if it is used to compare equations estimated in different dimensions, such as level and percent-change form. The $\bar{R}^2$ will usually be much lower in the change form than the level form, because of greater random variation relative to the systematic variation in the change form than in the level form. In this case, a better measure of goodness of fit is the standard error of the regression.

Standard error of the regression (SER): This is another measure of the explanatory power of the equation. It measures the degree to which the estimated values of the dependent variable differ from the actual values. Given a normal distribution of errors, we would expect that the fitted value of the dependent variable would be within one standard error (plus or minus) of the actual value 66 percent of the time.

Durbin-Watson statistic (DW): This statistic tests for first-order autocorrelation, i.e. systematic errors in the estimated equation. A common cause of systematic error is the omission from the equation of at least one significant explanatory variable. For our particular equations, DWs of greater than 1.6 indicate, with 95-percent confidence, a lack of positive autocorrelation. In testing for negative autocorrelation, DWs of less than 2.4 indicate, with 95-percent confidence, a lack of negative correlated errors. If the DWs fall between 1.2 and 1.6 or between 2.4 and 2.8, then the respective tests of autocorrelation are indeterminate—that is, we cannot conclude from the tests whether or not systematic errors are present. DWs of less than 1.2 indicate significant positive first-order autocorrelation, and DWs greater than 2.8 indicate significant negative first-order autocorrelation of the errors.

FOOTNOTES

1. These models usually have involved analyses of the effects of changes in inflation expectations. In the monetary approach, a rise in inflation expectations will reduce the real demand for money, putting additional upward pressure on prices which is initially observed in the foreign-exchange rate. In the portfolio approach, a change in inflation expectations, operating through the bond market, will reduce the desired holdings of assets in the inflating currency and thus affect the exchange rate. The monetary approach assumes prompt adjustment in the goods market to a monetary disturbance which is observed in the exchange rate but (because of measurement error) not observed in price indexes. In the portfolio approach, goods markets presumably adjust with a lag, but the bond market responds immediately and thus affects the exchange rate. Either of these approaches could explain a short-run exchange-rate change which is greater than observed changes in the ratio of national price levels. Both approaches accept implicitly or explicitly the assumption of long-run purchasing-power parity.

2. For an opposing viewpoint on currency substitution and a discussion of the effects on the exchange rate, see Wallace (1978, 1979).

3. The terms of trade measure the long run value of one country's goods in terms of the value of another country's goods, e.g., how many bushels of U.S. wheat it takes to "purchase" one Japanese TV set. A change in the terms of trade could be caused by a change in technology, the discovery of new sources of raw materials, or a substantial change in relative prices of important commodities, such as a rise in the price of oil. We assume here that terms of trade changes are independent of monetary factors.

4. Equation 8 assumes that risk premiums are equal across countries. This is done for simplicity and is not necessary for the model. All that we really need to assume for the model to hold is that these risk premiums are constant across time, i.e., $r = r^* + c$. We are not attempting in this paper to model the consequences of long run changes in the real interest rate.

5. Equation 9 can be derived as follows:

$$R = \Delta P^e + r \qquad 5a)$$

$$R^* = \Delta P^{*e} + r^* \qquad 5b)$$

$$\Delta S^e = \Delta P^{*e} - \Delta P^e \qquad 7)$$

$$r = r^* \qquad 8)$$

Substituting 5a) and 5b) into 8 we get:

$$\text{or } R - \Delta P^e = R^* - \Delta P^e$$
$$\text{or } R = R^* - (\Delta P^e - \Delta P^e)$$

Substituting equation 7 into this, we arrive at equation 9:

$$R = R^* - \Delta S^e \qquad 9)$$

6. This topic is discussed in Bilson (1979).

7. Even in the long run, the relationship will not be exact, because price indexes in two different countries will not necessarily have the same weights. That is, even if individual goods are priced the same in two countries, the price indexes may not necessarily have the same value in the two currencies because of differences in the composition of the indexes. To minimize these cross-country measurement problems, wholesale rather than consumer prices are used here. Furthermore, the existence of long-run purchasing-power parity does not imply anything about the direction of causality, the theory only requires that prices and exchange rates move together. Not only will prices affect exchange rates, but exchange rates will also affect prices. The crucial factor determining both prices and exchange rates is the difference in excess money growth between countries.

8. See Carr and Darby (1977) and Tucker (1971).

9. Charles Pigott discusses these lags in his article in this issue, "Expectations, Money and the Forecasting of Inflation."

10. The market-adjustment lag also includes the time it takes for a monetary disturbance, once recognized, to alter individuals' behavior. This lag arises because each individual tends to economize on decisions and transactions, and thus changes his behavior only periodically, even after the monetary change is considered permanent. On the aggregate level, this implies a gradual change in demand and supply.

11. A large number of organized, auction-type markets exist, where a large number of buyers and sellers trade a single homogeneous product, and where the costs of holding inventories and transporting the product are not prohibitively high. (The importance of these conditions is illustrated by the case of GNMA vs. regular mortgages. The creation of GNMA mortgages served to homogenize the product and enable the establishment of both spot and future markets. See Froewiss, 1978.) These requirements are most applicable to financial assets. A large number of secondary markets have been organized for trading in stocks and bonds, and there are also organized markets—foreign exchange markets—for the buying and selling of national currencies. There are also auction-type markets for certain goods, primarily raw commodities such as wheat and soy beans. In general, however, most assets are traded on organized auction-type markets while most goods and services are not.

12. Adjustment lags for most goods prices are frequently attributed to the existence of fixed purchase-and-sale contracts. The existence of contracts per se does not cause these adjustment lags; after all, bonds represent fixed contracts also. Rather, the lags are due to the fact that these contracts are non-negotiable, i.e., no organized market exists for the purchase and sale of contracts for such goods.

13. Actually, a large enough change in one or two of these factors could reverse the sign(s), of the effects on the other factor(s), while still maintaining money-market equilibrium.

14. See Tucker (1971).

15. Equation 9 is a covered arbitrage condition only if ΔS^e is interpreted as log F − log S, where F is the forward exchange rate. Equation 9 then represents covered or closed interest parity. For this paper, we only assume that ΔS^e is the expected appreciation, log S^e − log S. If the forward rate is equal to the expected future spot rate then this will be a covered arbitrage condition, and if not equation 9 represents uncovered or open interest parity. See Frankel (1979) for a further discussion.

16. One additional short-run effect is not mentioned explicitly in the text. The permanent increase in the long-run expected inflation rate, and thus in the long-run interest rate, will cause a one-time reduction in the level of real money demand (due to movement along the money-demand curve). Thus, a permanent increase in the **rate of growth** of money will result in an additional one-time increase in the **level** of prices and a one-time decrease in the **level** of the exchange rate. To our knowledge, the quantitative importance of this effect has not been estimated.

17. For an example of an attempt to distinguish between anticipated and unanticipated money-supply changes see Barro (1978).

18. The relative magnitudes of expected and unexpected money changes for each country may be estimated roughly by examining the ranking of the means and variances of changes in excess-money ratios. The means give us an approximation of average expected excess-money growth over the estimation period, and the variances around the mean give us an approximation of unexpected excess money. We discovered, however, that the rankings of the means were approximately the same as the rankings of the variances—i. e., those countries with higher means also had higher variances of excess-money growth. Thus, the ranking of the unexpected relative to the unexpected remained indeterminate.

19. We calculated the change in excess-money supply in any month as equal to the change in nominal money supply in that month minus the change in the 36-month moving average in real balances. We used averages between 60 and 24 months for estimating the Japan/U.S. equations and the results were not sensitive to the length of the moving average, except at the short end.

20. Because of the lack of earlier data, the estimation period for the Japanese long-run interest equation was 75.02 to 78.12. Because of the closing of the Italian foreign-exchange market in February-March 1976, a dummy variable was used in the Italian price equation (equal to 1 in Mar./April 1976, and zero elsewhere) and in the Italian exchange-rate equation (equal to 1 in February-April 1976 and zero elsewhere).

21. In the text we focus on whether or not the coefficients in the price and exchange-rate equations are different from each other. While the two sum coefficients for each country are not statistically different from each other, a number of them are significantly different from one. Given the fundamental postulate of neutrality of money, how is it possible for monetary disturbances to have more than a proportionate effect (i.e., coefficients greater than one) on prices and exchange rates? Changes in the excess-money supply may perhaps be measured improperly, either because of an inappropriate definition of nominal money supply or because of an inappropriate measure of real money demand. Since money-supply data are available from standard statistical sources, and since money demand here is derived artificially as a 36-month moving average of the real money stock, the most likely source of error probably arises from the demand side. For example, current increases in money growth may generate expectations of similar future increases, and may therefore raise inflation expectations. This would cause people to economize on cash balances, i.e., reduce the quantity of money demanded. We have tried to account for this by using "excess money" instead of actual money, but our variable probably did not totally capture this effect. Consequently, we would expect the coefficients to be larger than one in both the exchange-rate and price equations. Pigott, in his article in this issue, discusses other reasons why these coefficients may be greater than one.

22. It was assumed for the t-test on the difference of the long run coefficients that this difference was normally distributed with variance estimated by the sum of the estimated variances of the coefficients minus twice their covariance. Their covariance was estimated by the correlation between the errors of the equations times the product of the estimated standard errors of the coefficients.

23. The French coefficient is significant only at the 90 percent confidence level.

24. Capital flows from France are subject to exchange-control approval, and are generally restricted. In the long run, most of the controls may be circumvented, but a complex system of administrative regulations still makes capital transactions very cumbersome. (See IMF, 1979.) This implies that adjustment of the exchange rate must occur through pressures which develop in the goods market rather than in the asset market. This is probably the reason why the French exchange rate adjusts at virtually the same speed as prices to a monetary disturbance, despite the existence of a liquidity effect in the short-term interest-rate equation.

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