On Exchange Rate Dynamics

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Experience since early 1973 has shown that under a system of floating exchange rates currency values may fluctuate considerably over relatively short time periods. Some have blamed this observed volatility on excessively destabilizing or insufficiently stabilizing speculation, while others have attributed it to instability in underlying economic conditions or to disruptive official macroeconomic policies.

In the engoing debate, the monetary or asset approach to payments analysis has played a prominent role.[1] In the relevant class of models, the properties of stock adjustment in asset markets as well as "rational" processes of expectations formation have received critical attention. The results obtained, however, have turned out to be quite sensitive to the details of model specification. *Dornbusch* (1976), for example, works with a model which, in addition to postulating rational expectations, assumes that rigidities in the commodity market force prices to be adjusted gradually rather than all at once. He finds that both the instantaneous and the steady state price of foreign exchange rise in response to a monetary expansion, but that the former may rise by more than the latter, hence setting up the expectation of a subsequent appreciation of the domestic currency.[2] The short-run exchange rate is thus more volatile than its steady state value and this phenomenon of "overshooting" is offered as an explanation of recent exchange rate behavior. By focusing on rational expectations in the exchange market, on delayed adjustment in the commodity market and on the role of

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[1] See, for example, *Dornbusch* (1976), *Frenkel* (1976), and *Kouri* (1976).

[2] A similar formulation is found in *McKinnon*.

monetary aggregates, the approach differs sharply from more traditional explanations of short-run behavior in exchange markets.[3]

The short-run impact of a monetary shock depends critically on relative adjustment speeds in the various sectors of an open economy.[4] It depends also on the pattern of expectations and on the extent to which agents act on their expectations. An important feature of recent applications of the rational expectations hypothesis to exchange rate dynamics is the selectivity with which the rationality postulate is invoked. Typically agents are assumed to act on their expectations in the exchange market but not elsewhere.

This paper examines the short-run behavior of exchange rates within a portfolio-balance framework with three important characteristics. First, while commodity prices are taken to be less flexible in the short run than exchange rates, price adjustment, whenever it does occur, is assumed to be complete rather than piecemeal and gradual. Second, agents are assumed to act rationally in the commodity market as well as in the exchange market. In particular, the anticipation of an upward revision of prices creates incentives for commodity stockpiling as an inflation hedge. Third, certain restrictions are imposed on the portfolio choices of the various participants.

It is found that the stockpiling option imposes critical requirements on the path of nominal interest rates which serve to reduce the short-run volatility of exchange rates. In essence, the initial burden of adjustment to a monetary shock is shifted from the exchange rate to the rate of interest; under certain conditions, the exchange rate remains initially relatively unaffected by the disturbance and adjusts only when commodity prices themselves are adjusted.

In addition, it is shown that efforts by the monetary authorities to impede or delay the response of interest rates to the disturbance, prevent the aforementioned shifting of the adjustment burden and lead directly to greater volatility in exchange rates. Moreover, there need under these circumstances be no systematic relationship between interest rates and exchange rates or between exchange rates and monetary aggregates.

I. The Framework

Consider the following simple economy, made up of firms, households, commercial banks and a monetary authority. There is a market for "goods" and one for labor, with the latter assumed to be in continuous

[3] See *Artus* (1976) for a recent attempt to identify destabilizing or "bandwagon" speculation.

[4] In this connection, see *Allen* and *Kenen* (1976).

equilibrium at full employment. There is no real growth or accumulation of real capital. In addition to commodities and labor, there are markets for financial assets: for money (M), defined for simplicity as currency in the hands of the nonbank public; for time deposits (T), the yield (r_T) on which is fixed by law; for short-term government bonds (B), and for foreign bonds (F) with a fixed yield of r^*. Finally, a private bond (S), a perfect substitute for B, is issued by firms. We assume that commercial banks alone hold B, F and S, that firms hold working balances of M and that households hold M and T.

In the short run, the stock of domestic government bonds is fixed and may be altered only by intervention of the monetary authority. By virtue of the small country assumption, which holds for most of the analysis, the supply of the foreign bond is infinitely elastic and thus the yield, r^* (in terms of the foreign currency), is fixed; changes in domestic holdings of F are possible over time through appropriate variations in the trade balance surplus.

Firms hire factors and produce and sell commodities. To the extent that they carry inventories, they do so to meet contingent variations in demand. Under certain circumstances to be spelled out below, however, they may engage in commodity stockpiling as a hedge against inflation.

A simple period analysis is used in which the length of the period is defined by the price-setting behavior of firms. It is assumed that commodity prices are posted at the start of the period and that they cannot be changed again until the next period.[5] Interest rates, exchange rates and certain other decision variables, on the other hand, may be revised at various points during the period.

At the start of each period, three types of decisions are made: stocks of assets to be held initially; additions to be made to stocks during the period; and flows of production and consumption during the period. All known and anticipated disturbances are built into decisions at this time. Prices, interest rates and exchange rates are adjusted so as to clear all markets.[6] While all critical variables are thus adjustable at the beginning of each period, the system's response *during* the period is restricted to a subset of these variables: neither commodity prices nor production and consumption plans may be altered.

Thus, if at some point during the period an unanticipated disturbance creates excess demand in the commodity market at the price level set

[5] For a distinction between beginning-of-period and end-of-period formulations and their continuous-time counterparts, see *Foley* (1975).

[6] For convenience, it is assumed that commodity prices are initially set so as to render the expected rate of inflation (π) and thus the expected depreciation of the currency equal to zero.

at the start of the period, agents are assumed to use the relevant model to calculate the price which would clear the market. Since the posted price cannot be altered until the next period, however, the calculated price becomes the expected price and, on the assumption that in the long-run exchange rates follow purchasing power parity, the calculated future price yields the exchange rate expected for the future. On the basis of these revised estimates of future price level and exchange rate, participants review their positions in all markets and adjust their behavior accordingly. As a result of such revisions, both the rate of interest and the rate of exchange are likely to be different from those set at the start of the period and from those likely to rule at the start of the next period. In a period characterized by frequent unanticipated disturbances, the two variables may display frequent changes.

II. Unanticipated Monetary Shocks and Short-Run Exchange Rate Behavior

Suppose that starting with the economy initially in short-run equilibrium, the system is disturbed by an unanticipated Central Bank purchase of government bonds. Suppose, further, that agents take this to be a once-for-all change in the money supply. In accordance with rational expectations, agents use the relevant model to calculate the new (and higher) equilibrium price level and thus the rate of price increase (π) expected between the two periods. On the assumption that purchasing power parity governs the long-run behavior of the exchange rate and that the expected rate of foreign inflation is zero, the expected future price of foreign exchange ($\hat{e}_2$) is given by expression (1)

$$\hat{e}_2 = e_1 (1 + \pi) \tag{1}$$

where $\hat{e}_2$ is the price of foreign exchange expected to rule at the start of period 2, e_1 is the exchange rate which rules at the start of the present period, and π is the rate of expected inflation. Throughout, e without a subscript will refer to the exchange rate at various points during the period.[7]

If commodity prices were variable, they would increase immediately to reflect the unanticipated expansion; under conditions of long-run neutrality, the price level would increase in proportion to the increase in the supply of money and the spot exchange rate would rise accordingly in order to fulfill the requirements of purchasing power

[7] Under appropriate and familiar assumptions about the substitutability of foreign and domestic assets and about exchange market efficiency, the current forward rate will be an unbiased estimator of the future expected spot rate.

parity. The nominal interest rate would remain unchanged. (The liquidity effect, tending to depress the rate of interest, will be offset by the real balance effect of a rising price level).[8] Prices cannot be altered until the next period, however, so that the burden of adjustment must initially be borne by other variables in the system.

It is important to note that firms, having calculated the price which would clear the commodity market, plan to make the full price adjustment whenever they first get the chance. This is in marked contrast to some recent treatments, notably those of *Dornbusch* and *McKinnon,* in which prices are adjusted piecemeal and smoothly. The latter process is difficult to reconcile with the assumption of full information, rational expectations employed in these models. It is more readily reconciled with certain limited information forms of the rational expectations hypothesis[9] and also with various adaptive expectations processes.

The assumption of gradual adjustment raises empirical difficulties as well, for it suggests that under most monetary shocks price changes will be serially correlated. *Sweeney* (1975) has argued, that this is inconsistent with efficient information processing in output markets and with evidence suggesting that inflation rates tend to be serially uncorrelated when proper attention is paid to shifts in the mean inflation rate.

Asset Market Adjustment: The Non-Household Sector

In selecting their portfolios, agents are influenced by pecuniary and non-pecuniary returns on alternative assets and by risk considerations. Where assets differ with respect to risk, portfolios will be diversified and assets with divergent rates of return will be found in wealth owners' portfolios. Where all returns are subjectively certain, two assets will both be held only if their returns are equal. The following discussion is confined to the case of perfect substitutability among assets. The behavior of firms and commercial banks is examined in this section, while household behavior is taken up in the next. The effects of monetary shocks on the system as a whole are discussed in a following section.

Prior to the shock, the system is in short-run equilibrium, implying that at the margin total (i. e., pecuniary and non-pecuniary) returns to financial assets are equal. The expected inflation, brought about by

[8] The discussion focuses on instantaneous asset market adjustment and ignores changes in wealth through the trade balance. For a recent analysis of asset-market behavior in the context of instantaneous price adjustment, see *Kouri* (1976).

[9] See, for example, *Barro.*

the open-market purchase, affects all domestic assets approximately equally: it lowers, at initial nominal rates, their real rates of return by approximately the same proportion.[10] The foreign asset (F), on the other hand, is affected differently: under rational expectations the expected future spot rate rises with the expected rate of inflation, meaning that the nominal return rises along with the anticipated inflation and that the real rate of return remains unchanged.[11]

At initial interest and spot exchange rates, the foreign asset is a superior inflation hedge and demand for it increases. In order to maintain short-run equilibrium, therefore, the spot rate (e) and/or the rate of interest must rise relative to their beginning-of-period values. However, the required combination of exchange rate and interest rate changes is not arbitrary, for so long as the domestic rate of interest is below the level which covers the expected rate of inflation, commodity stockpiling will offer better protection against inflation than domestic financial assets. If, for convenience, real rates of return and storage costs are ignored, the nominal rate of interest must equal the expected rate of inflation in order to eliminate incentives for stockpiling.

Since the stock of commodities available at any moment is fixed, agents cannot instantaneously satisfy their desires to hold larger commodity stocks. Knowing, however, that prices will not be raised until the beginning of the next period, they have an interval during which to bring actual stocks into line with desired stocks. If we assume for convenience that firms rather than households do the hoarding and if we suppose further that the flow rate of output cannot be altered in the short run, the only remaining avenue open to would-be commodity hoarders is to change the allocation of the flow supply of output by diverting portions of it from sales into inventories. In order to finance such additions to stockpiles and to compensate for lost sales revenues, hoarders issue private bonds (S).

Hoarding incentives will persist and private securities will continue to be offered until the nominal rate of interest has risen to correctly reflect inflationary expectations. These considerations suggest the following cases.

Case I: Stockpiling Ruled Out

In equilibrium, returns on the three financial assets must be equalized. Comparing returns on the two bonds, we write

[10] Approximate because of possible second-order effects.

[11] Strictly speaking, this is true only for newly acquired foreign assets and for uncovered existing holdings. Foreign assets held at the time of the shock and covered at the initial forward exchange rate are affected in a manner quite similar to domestic assets.

$$1 + r = \frac{\hat{e}_2}{e}(1 + r^*)$$

or

$$e = \frac{1 + r^*}{1 + r}\hat{e}_2 \tag{2}$$

What expression (2) tells us is that for a given foreign rate of interest the system will react to an unanticipated monetary expansion in a way which brings the current spot rate into line with the prevailing domestic rate of interest and the expected future exchange rate. A monetary expansion raises the expected price of foreign exchange ($\hat{e}_2$); if the domestic rate of interest remains unchanged, the spot rate rises relative to its value preceding the shock but not relative to the new expected exchange rate. If the rate of interest falls, as it must with a dominant liquidity effect in the absence of stockpiling and as is assumed in *Dornbusch* and *McKinnon*, e rises relative to $\hat{e}_2$ and thus generates the necessary expected appreciation of the currency. This initial depreciation of the current spot rate relative to its longer-term value *Dornbusch* has called "overshooting".

Apart from questions concerning the conditions under which such overshooting will occur, there is a difficulty in interpreting the expected future exchange rate. In a number of recent theoretical treatments of exchange rate dynamics, the relevant value of the exchange rate which is overshot is the steady state value. In practical discussions of recent exchange market history, however, some observers have interpreted any quick reversal in the observed exchange rate as signifying overshooting. Such judgments depend critically on whether the future expected exchange rate is viewed as an equilibrium rate or as one which itself fluctuates around a long-term trend value. In part, this reflects the difficulty under flexible exchange rates of defining the meaning of the equilibrium exchange rate. To some it is simply the rate which, given the totality of forces operating in the market at a given moment, clears that market. To others, it takes on a more profound meaning reflecting the confluence of "basic" forces from which ephemeral, if not immoral and certainly economically unproductive, speculation is to be excluded.

Case II: $r^* = \pi^* = 0$; Stockpiling in the Home Country

An unanticipated monetary expansion generates the expectation of a price increase at the start of the next period. Consequently, the expected price of foreign exchange ($\hat{e}_2$) rises in proportion to the expected inflation. At initial interest and spot exchange rates, commodity stockpiling clearly represents a preferred inflation hedge and the demand

for stocks to be held rises. While stocks cannot be increased instantaneously, it is assumed that the allocation of the flow supply of output between sales and inventories is altered in favor of the latter and that additions to stocks are financed by debt issue (S).

In the absence of storage and spoilage costs and ignoring real rates of return, incentives to stockpile and to issue debt will persist until condition (3) obtains.

(3) $$r = \pi$$

Incentives to switch between bonds and commodities will persist until condition (4) holds.

(4a) $$e = \frac{1}{1+\pi}\,\hat{e}_2$$

and thus

(4b) $$e = e_1$$

Condition (4a) relates the spot rate at any moment during the period to the expected rate of inflation and to the expected rate of exchange. The two expectations variables are, of course, related and may change several times during the period depending on the nature and frequency of unanticipated monetary disturbances. Condition (4b), on the other hand, states that while expectations about price inflation and currency depreciation may change, the spot rate remains initially unchanged at its beginning-of-period value. This follows from the fact that the rate of interest adjusts fully to absorb the impact of the disturbance. The exchange rate will not reflect the effect of the disturbance until the new prices are posted in the next period.

This result, which depends crucially on the inflation-hedging activities of goods market participants, stands in striking contrast to conclusions reached in models without stockpiling. It suggests that the short-term exchange rate will be relatively stable and will proceed to its long-term value directly rather than via a path characterized by overshooting.[12]

Case III: $r^* = \pi^* > 0$

This case is analogous to the previous one except that the (given) foreign rate of inflation and thus the foreign nominal rate of interest

[12] While the discussion has been simplified by ignoring the consequences of positive real rates of return on financial assets, introduction of real rates does not affect the essentials of the analysis.

are positive. Condition (5) is analogous to condition (4) in the previous case.[13]

(5a) $$e = \frac{1 + \pi^*}{1 + \pi} \cdot \hat{e}_2$$

and

(5b) $$e = e_1$$

Thus, once again the result of stockpiling, which drives the nominal rate of interest to match the expected inflation rate, is an initially unchanged spot exchange rate. There is no possibility of overshooting so long as the nominal rate of interest moves to reflect inflationary expectations. Moreover, this conclusion is not altered when the small-country assumption is dropped, provided that stockpiling abroad maintains consistency between foreign interest and expected inflation rates.

Adjustment in the Household Sector

The preceding discussion has dealt with the behavior of firms and has not considered the consequences for households of business sector stockpiling. Stockpiling diverts portions of the flow supply of current output from the market and thus prevents households from realizing their planned purchases at prevailing prices. With planned savings and planned net imports not instantaneously adjustable, realized household savings exceed desired savings. The only choice open to households is the allocation of this undesired increase in savings between cash balances and time deposits. When the expected rate of inflation is positive, the ratio of time deposits to money in household portfolios will clearly increase.[14]

Disequilibrium Dynamics

The process sketched in the preceeding paragraphs recognizes that trading in the commodity market may take place at non-market clearing prices. Normally, specification of demand and supply functions rests on the premise that by means of tatônnement and recontracting agents may always expect to realize their transactions derived from

[13] When inflation rates are positive in both countries, the relationship between future expected exchange rate and the rate ruling at the start of the current period is given approximately by

$$\hat{e}_2 = e_1 \frac{1 + \pi}{1 + \pi^*}$$

[14] The allocation between the two assets, as well as reserve requirements and commercial bank behavior, determine the ultimate expansionary effect of the open-market purchase.

utility and profit maximization. Trading occurs only when a market clearing price has been established, and planned and realized magnitudes are always identical. We shall refer to the demand and supply functions relevant to this process as *prior* or *notional* functions.

These functions and the actual and desired magnitudes they represent must be distinguished from functions and magnitudes which incorporate the spillover effects of false trading, that is, of trading experiences in which agents find that in one or more markets they cannot realize their planned transactions. In our present example, households had at the beginning of the period utilized all available information and in the context of their preferences established flow demands for goods and stock and flow demands for assets — all at prices which were at the time market-clearing prices. The monetary shock and the resulting diminution of the flow supply of commodities produce a situation of false trading in the goods market, that is, a situation in which households cannot carry out their original absorption plans. The mirror image is the increase in their assets relative to savings originally planned. Their money balances will clearly be greater than indicated by their prior money demand functions.

Given the expected rate of inflation, however, some substitution between cash and time deposits will take place. As a result, time deposits will also be larger than indicated by prior asset demand functions; and the commercial banking system will experience liability changes different from those predicted on the basis of prior functions. These changes are all the result of spillover effects originating in the commodity market; functions incorporating spillover effects we characterize as *posterior* or *effective*. At given yields on time deposits and given prices in other markets, the posterior demand for both time deposits and cash balances will temporarily be greater than the relevant prior demands.[15]

IV. Implications for Exchange-Rate Policy

In this section several implications of the preceding discussion are examined.

1. Consider the case of a country whose monetary authorities pursue an interest-rate target by engaging in open-market operations whenever

[15] For the distinction between notional and effective demand and supply, cf. *Clower* (1965). See also *Barro* and *Grossmann* (1976) and *Benassy* (1975) for analyses using these concepts. For an examination of the meaning of the demand for money in the presence of false trading, see *Tucker* (1971). For an application of the disequilibrium approach to open economies, see *Arndt* (1976, 1977).

the domestic rate of interest drifts away from a predetermined value. Thus, a tendency for the rate of interest to rise in several of our examples is met by Central Bank purchases of securities, say, the private securities (S) issued by stockpiling firms.

This policy clearly adds to existing inflationary expectations and thus causes the expected future spot price of foreign exchange to rise further. To the extent that the policy succeeds in temporarily slowing the increase in the rate of interest relative to rising inflationary expectations, condition (6b) which

$$e = \frac{1 + r^*}{1 + r}\,\hat{e}_2 \tag{6a}$$

$$e = \frac{1 + r^*}{1 + r} \cdot \frac{1 + \pi}{1 + \pi^*} \cdot e_1 \tag{6b}$$

is a variant of condition (5b) shows that the burden of adjustment is shifted to the current spot rate which rises.[16]

In the limit, if the interest rate is initially prevented from changing, the current and expected future spot rates move together, as condition (6a) indicates. Then, as the interest rate inevitably begins to catch up with inflationary expectations, the current spot rate declines relative to the expected future spot rate. At the beginning of the next period, however, when prices are moved to their market clearing (higher) levels, the spot rate increases again, this time to its purchasing power value $\hat{e}_2$, unless developments dictate further adjustments. At the same time, the interest rate climbs down from the high level reached during the period when commodity prices were unable to reflect the rising inflationary pressures.

The behavior of the spot rate during the period of immobile prices may look something like the path traced in Figure 1. In that figure, the stylized sequence begins with a monetary expansion which raises the expected future spot rate to $\hat{e}_2$. The interest rate remains temporarily unchanged. As a result, the current spot rate rises from e_1 to $\hat{e}_2$. Any further monetary expansion not accompanied by interest rate increases pushes up the expected and current exchange rates, say, along the path leading to e_2'. Then, as the interest rate rises to its market-determined value, the current spot rate drops to e_1 either directly along the solid path or more gently along the dotted path.[17] Then, at the beginning

[16] A similar outcome follows from a policy which combines monetary expansion with regulatory or statutory ceilings on interest rates.

[17] The expected future spot rate may or may not continue to rise depending on what happens to the money supply.

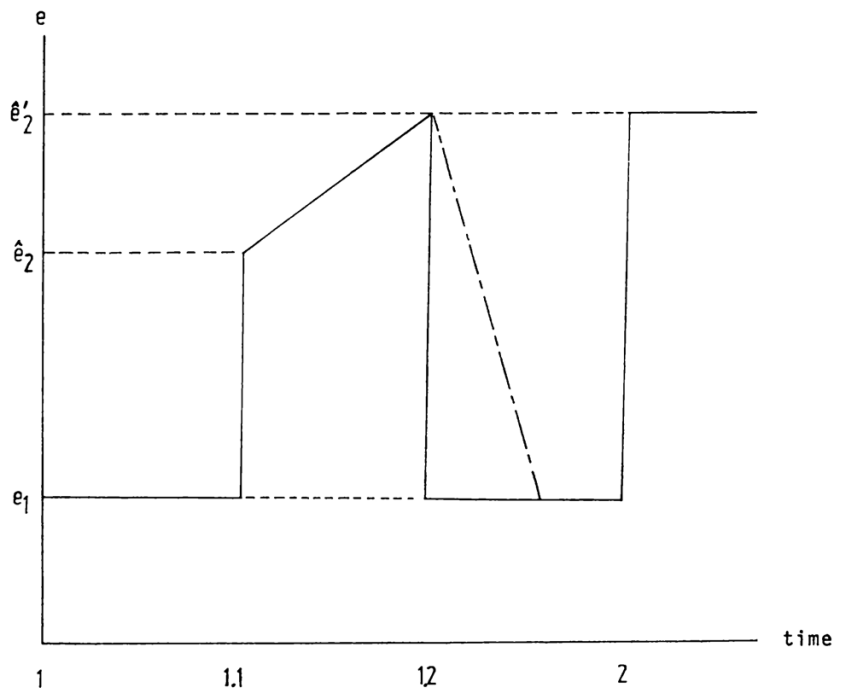

Fig. 1

of the next period, when full adjustment of commodity prices is achieved, the spot rate rises to its "long-run" value ($\hat{e}'_2$) determined by purchasing power parity considerations.

By changing the speed at which the interest rate is permitted to adjust to changes in inflationary expectations, we are thus able to generate an exchange rate path which has all the appearances of exchange rate behavior in recent years. Note that a more aggressive monetary expansion in the foreign country will not slow the foregoing upward pressures on the current spot rate as long as the foreign interest rate adjusts fully to inflationary pressures.

2. If one embarked on an effort to empirically test the relationship between interest and exchange rates, a world which resembled the one sketched in the preceding discussion would create an investigator's nightmare. Consider the following possibilities:

(i) When the interest rate is allowed to move freely in order to reflect inflationary expectations, the spot rate remains unchanged during

the period, that is, we observe a steady exchange rate while monetary aggregates and interest rates are rising. Aggregates and interest rate move in the same direction.

(ii) When the interest rate is prevented from rising or when its increase is retarded, the current spot rate will rise, i. e., we observe a rising spot rate and a steady or rising interest rate and a rising money supply. Aggregates, interest rate and exchange rate move in the same direction or at least not in opposite directions.

(iii) When an interest rate, which had been held back or retarded, is eventually allowed to move, the exchange rate falls. Interest rate and exchange rate move in opposite directions. The monetary aggregate may or may not be moving in the same direction as the exchange rate.

Thus, it is possible for the money supply to be expanding, while interest and exchange rates move in the same or opposite direction. This may explain why it has been so difficult empirically to identify some of the simple relationships postulated in many recent models and discussions.[18] The foregoing discussion suggests that natural lags in price adjustment may lead to a temporarily steady exchange rate in the face of inflationary pressures and expectations, provided that interest rates are allowed to bear the initial burden of adjustment. In the face of changing excess demands, however, something must give and some price must adjust. There is room for argument whether some prices should bear more of the burden of adjustment initially than others, and some interesting welfare implications may lurk here, but what is not possible is that pressures be bottled up entirely. Thus, a country which fixes prices by means of an "incomes policy" and then imposes a similar policy on interest rates, cannot be surprised that its exchange rate bears not only the brunt of the initial adjustment but is whipsawed as other prices adjust at various natural or unnatural speeds.

3. Consider next the case of two countries with identical inflation rates and with an interest rate-fixing policy in the home country. In this case, the expected future spot rate remains unchanged, while the pursuit of an interest target forces the home currency to depreciate immediately in the spot markets and to appreciate in the next period. This represents a straightforward example of the overshooting phenomenon.

[18] For recent empirical studies, see *Arndt* and *Pigott* (1977) and *Kaylin* et al. (1976).

Conclusion

Even in a world with sluggish price adjustment in the commodity market, the short-run exchange rate will be quite stable provided that (i) commodity market participants act on their inflationary expectations by increasing their stocks and (ii) the nominal rate of interest is free to move to levels which reflect inflationary expectations. In such a world attempts by the monetary authorities to prevent the interest rate from responding to inflationary pressures will shift the burden of adjustment to the exchange market and raise the short-run volatility of the exchange rate.

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