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I. Introduction

The evolution of the international monetary system into a regime of flexible exchange rates and the large volatility of these rates during the 1970's have led to a renewed interest in studying the principal determinants of equilibrium exchange rates. The large fluctuations stimulated theories of exchange rate dynamics and have led to the development of various versions of overshooting hypothesis.[1] The explanations of the overshooting phenomenon vary. All explanations rely on the short-run fixity of some nominal quantity. Some account for it by the assumption that in the short run commodity prices are slow to adjust relative to asset prices [Dornbusch (1976)]; some attribute it to the lack of sufficient speculation in the markets for foreign exchange [McKinnon (1976)]; some attribute it to the differential effects of new information on commodity and asset markets [Dornbusch (1978), Frenkel (1980), Frenkel and Mussa (1980), Mussa (1979)] and some attribute it to the implications of the process by which asset holders restore portfolio balance in the face of disturbances [Calvo and Rodriguez (1977), Branson (1979), Kouri (1976), Ethier (1979)].[2]

In this paper we analyze the implications of two classes of models for the dynamics of exchange rates. We assume throughout that expectations are formed rationally and that individuals are fully informed. We therefore

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[1]For a classification of the various versions of the overshooting hypothesis, see Levich (1979).

[2]In addition to the studies mentioned above, a partial list of recent studies includes Bilson (1979), Flood (1979), Henderson (1979), Kimbrough (1980), Liviatan (1980), Mussa (1980a) and Shafer (1980). Further references are included in the following sections of this paper.

preclude the possibility that the dynamics of exchange rate is due to systematic expectational errors.

In section II we analyze the dynamics of exchange rates in a model in which commodity prices are slow to adjust. The basic structure of the model is due to Dornbusch (1976). Our extension allows for a finite rate of capital mobility and we show that the speed of adjustment in capital markets plays a critical role in determining whether or not following a monetary disturbance the exchange rate overshoots its equilibrium value. It is shown that when the degree of capital mobility is low, the exchange rate is likely to undershoot its equilibrium value.

In section III we analyze the dynamics of exchange rates within the framework of the portfolio-balance model with complete flexibility of prices. In this context we interpret earlier results of Calvo and Rodriguez (1977) concerning the effect of monetary growth on the real exchange rate. We show that the fundamental factor determining the dynamics of the real exchange rate is the specification of the portfolios of assets, the degree of capital mobility and the relative qualities of the various assets as hedges against inflation. The study of the dynamics of the real exchange rate shows that throughout the adjustment process the nominal exchange rate is changing at a rate which differs from the rate of inflation. It follows that a policy which ties the exchange rate to the rate of inflation would be inconsistent with the equilibrium self-fulfilling expectations adjustment path.

II. Exchange Rate Dynamics and the Speed of Adjustment in Commodity and Asset Markets

In this section, we analyze the dynamics of exchange rates and the overshooting hypothesis from the perspective which emphasizes the speeds of adjustment in commodity and asset markets. This perspective was developed by Dornbusch (1976) who assumed that, as a first approximation, asset markets clear instantaneously while adjustment in commodity markets is sluggish. Dornbusch showed that when these assumptions are coupled with the assumption that expectations are rational, a monetary expansion induces an immediate depreciation of the currency in excess of its long-run equilibrium value; i.e., a monetary expansion results in an overshooting of the exchange rate. To gain further understanding into the relationship between the dynamics of exchange rates and the speeds of adjustment in goods and asset markets, we modify the Dornbusch model and allow for a finite speed of adjustment in asset markets. It is shown that under these circumstances the key factor determining whether the exchange rate overshoots or undershoots its equilibrium value is the relationship between the speed of adjustment in asset markets, the interest elasticity of the demand for money and the effects of relative prices on the balance of trade. The speed of adjustment in commodity markets does not seem to be a fundamental factor.

Our analysis draws on the analytical framework developed by Dornbusch (1976) and, in order to highlight the key point, we simplify the model by abstracting from many of the inconsequencial details. We assume that the economy faces a given price of foreign output and a given world rate of interest, that domestically produced goods differ from foreign goods, and that the supply of output is fixed.

II.1 The Money Market

Let the demand for real balances depend on real income, Y, and on the rate of interest, and let the logarithm of the demand be linear in the logarithm of income, y, and in the rate of interest, i. Equilibrium in the money market attains when

$$(1) \qquad m - p = \phi y - \frac{1}{b} i$$

where m and p denote, respectively, the logarithms of the nominal quantity of money and the price level. Thus, the equilibrium rate of interest can be written as:

$$(2) \qquad i = b\phi y - b(m - p).$$

II.2 The Goods Market

The demand for domestic output, D, is composed of domestic demand and foreign demand. This demand can be expressed as the sum of total domestic absorption (domestic demand for domestic and foreign goods) and the excess of exports over imports (the trade balance surplus). Absorption is assumed to depend on real income, while the trade balance is assumed to depend on the relative price of domestic and foreign goods.[1] Total demand for domestic output can therefore be written as:

$$(3) \qquad D = A(Y) + T(SP^*/P)$$

where A denotes domestic absorption, T denotes the balance of trade, S denotes the exchange rate (the price of foreign exchange in terms of domestic currency), P* the fixed foreign price level (in terms of foreign currency) and P the price of domestic output. For convenience we define units so as to equate the foreign price level to unity; therefore, the trade balance may be viewed as depending on the real exchange rate s = S/P. Furthermore, since real output is given, absorption is fixed and the demand for domestic output varies with the real exchange rate.

[1]This specification abstracts from the effects of the rate of interest on absorption, the effects of income on the trade balance and the distinction between GNP and GDP that results from interest income on net ownership of foreign securities. These abstractions are made for simplicity since they do not affect the nature of the argument. Some of these factors are allowed for by Dornbusch (1976).

Long-run equilibrium obtains when the demand for domestic output equals the fixed supply, that is, when D = Y. We define the real exchange rate that is associated with this long-run equilibrium by $\bar{s}$. In order to abstract from long-run accumulation of foreign assets, we assume that in the long-run the trade balance is zero, so that $T(\bar{s}) = 0$. This assumption, that is made for convenience only, implies that absorption equals the given level of output (A(Y) = Y).

Proceeding with the log-linear specification, the trade balance is written as

$$(4) \qquad T = \delta \, \ell n\left(\frac{s}{\bar{s}}\right)$$

or equivalently as

$$(4') \qquad T = \delta(e - p - k)$$

where e, p, and k are the logarithms of S, P and $\bar{s}$, respectively. Substituting (4') in (3), and recalling that A(Y) = Y, the demand for domestic output is

$$(3') \qquad D = Y + \delta(e - p - k).$$

The percentage change in the price level, $\dot{p}$, is assumed to be proportional to excess demand (D - Y):

$$(5) \qquad \dot{p} = \pi(D - Y)$$

where the parameter π measures the speed of adjustment in the goods market.[1] Substituting (3') into (5) yields:

$$(6) \qquad \dot{p} = \alpha(e - p - k)$$

where $\alpha = \pi\delta$.

[1]The assumption that prices change at a finite speed is taken as a stylized fact and we do not attempt to rationalize it here. For an interesting theory of sticky prices see Mussa (1978). The specification of the rate of inflation as a function of excess demand is analogous to the specification in Dornbusch (1976), equation (8).

At each moment of time, the price level is given and its evolution is described by equation (6). The coefficient α is the product of two factors: π--the speed of adjustment in the goods market, and δ--the sensitivity of the balance of trade to the real exchange rate. As will be seen below, of these two factors only the latter plays a role in determining whether or not monetary changes result in exchange rate overshooting.

II.3 The Capital Account and the Balance of Payments

Equilibrium in the world asset market attains when the difference between the rates of interest on domestic and foreign securities, that are identical in all respects except for the currency of denomination, just equals the expected rate of change in the exchange rate. For example, when the domestic currency is expected to depreciate at the percentage rate x, long-run equilibrium requires that

$$(7) \qquad i - i^* = x$$

where i^* denotes the rate of interest on assets with foreign currency denomination. It is assumed that expectations concerning the percentage rate of depreciation depends on the relationship between the equilibrium long-run exchange rate $\bar{S}$ and the current rate, S. Expressed logarithmically,

$$(8) \qquad x = \theta(\bar{e} - e); \ \theta > 0$$

where $\bar{e}$ is the logarithm of $\bar{S}$ and where θ denotes the expectations adjustment coefficient, the determinants of which are analyzed below. Equation (8) states that when the long-run value, $\bar{e}$, exceeds the current value, e, individuals expect a depreciation of the currency towards $\bar{e}$, i.e., the expected depreciation, x, is positive.

The equilibrium that is described in equation (7) is attained through the mechanism of arbitrage that is effected through the international mobility of capital. It is assumed that capital flows are proportional to $(i - i^* - x)$-- the discrepancy between the net rates of return on the various securities. Substituting equation (8) for the expected depreciation of the currency, we can specify the international flow of capital as:

$$(9) \qquad C = \beta[i - i^* - \theta(\bar{e} - e)]$$

where C denotes net capial inflow (the surplus in the capital account) and where β denotes the speed of adjustment in asset markets.[1] When capital is perfectly mobile, $\beta = \infty$ and the mobility of capital ensures that equation (7) holds all the time. On the other extreme, when $\beta = 0$, capital is completely immobile and the mechanism of arbitrage in asset markets is completely inoperative. It is shown below that the magnitude of β is the key factor determining the dynamics of exchange rates.

Equilibrium in the balance of payments is attained when the sum of the trade balance and the capital account is zero. Adding equations (4') and (9) and substituting equation (2) for the (equilibrium) domestic rate of interest yield

$$(10) \qquad \delta(e - p - k) + \beta[b\phi y - b(m - p) - i^* - \theta(\bar{e} - e)] = 0$$

as the equilibrium condition for the balance of payments. It should be noted that the equilibrium condition for the balance of payments (which is a flow relationship) is necessary since the speed of adjustment in asset markets is assumed to be finite. When asset markets clear instantaneously, equation (10) always holds as an <u>identity</u> and the <u>equilibrium condition</u> is replaced by the interest parity condition as in equation (7) above.[2]

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[1] The theoretical deficiencies of the capital flow equation (9) are well known. Since our purpose is to highlight the role of alternative assumptions concerning the speed of adjustment in asset markets, we chose to specify the simplest formulation and to abstract from many other issues.

[2] For a discussion of the role of flow equilibrium when asset markets adjust slowly see Kouri (1976) and Niehans (1977). For a discussion of the conceptual issues involved in the formulation of flow equilibrium in asset markets see Mussa (1976). See also Driskill (1978).

II.4 Equilibrium Exchange Rate, the Speed of Adjustment and the Price Level

We turn now to an analysis of the equilibrium exchange rate and the relationship between the exchange rate, the price level, and the speed of adjustment in goods and asset markets. We first note that in the long-run, given the quantity of money, the exchange rate equals its long-run value[1] and $i=i^*$. Substituting i^* for i in equation (1)--the condition for money market equilibrium--the long-run price level, $\bar{p}$, can be expressed as

$$\bar{p} = m + \frac{1}{b} i^* - \phi y. \tag{11}$$

To obtain the relationship between $\bar{p}$ and $\bar{e}$, we note that in the long-run excess demand for goods is zero and, therefore, $\dot{p} = 0$; it follows from equation (6) that

$$\bar{e} = \bar{p} + k. \tag{12}$$

As may be seen from equations (11) and (12), the system satisfies the homogeneity postulate: a given change in the money supply results in an equiproportional change in the long-run equilibrium price level and the exchange rate. Using equations (11) and (12) in equation (10), we can write the equilibrium in the balance of payments as

$$\delta[(e - \bar{e}) - (p - \bar{p})] + \beta[b(p - \bar{p}) - \theta(\bar{e} - e)] = 0. \tag{13}$$

Equation (13) expresses the various accounts in the balance of payments as functions of the discrepancies between current and long-run values of the price level and the exchange rate. Since at each moment of time the price level is given, equilibrium in the balance of payments is obtained only when the exchange rate is at a level which satisfies equation (13). By collecting terms in (13), the equilibrium exchange rate can be written as

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[1]In the present framework the long-run value of the exchange rate is fixed. In general, the equilibrium value may be specified in terms of a movement along an equilibrium path; see Mussa (1980a).

(14) $e = \bar{e} + \varepsilon(p - \bar{p})$

where

$$\varepsilon = \frac{\delta - \beta b}{\delta + \beta\theta} \gtrless 0.$$

Equation (14), which is central to our analysis, relates the equilibrium exchange rate to its long-run value and to the discrepancy between current and long-run prices. This is a reduced form relationship which holds at each moment of time. It is pertinent to note that, depending on the sign of the parameter ε, the relationship between the price level and the exchange rate may be positive or negative. As may be seen, the sign of ε depends on the degree of capital market integration which we have characterized in terms of the speed of adjustment β. When the speed of adjustment is low, $\delta > \beta b$ and $\varepsilon > 0$. In that case, given $\bar{e}$ and $\bar{p}$, the exchange rate and the price level must move in the same direction. When the speed of adjustment is high, $\delta < \beta b$ and the opposite holds. In the extreme case for which $\beta = \infty$ the price level and the exchange rate are inversely related since in that case $\varepsilon = -(b/\theta) < 0$.[1] The determinants of the relationship between the price level and the exchange rate may be interpreted in terms of equations (10) or (13). For given long-run values of prices and exchange rates, a rise in the price level worsens the balance of trade and improves the capital account. The improvement in the capital account results from the rise in the rate of interest necessary to restore money market equilibrium in the face of a higher price level. The extent of the required rise in the rate of interest depends on b—the interest (semi) elasticity of the demand for money. When the speed of asset market adjustment is high, a given rise in the rate of interest results in a large improvement in the capital account, which is likely to more than offset the deterioration in the balance of trade. To restore equilibrium in the balance of payments, the domestic currency will have to appreciate (i.e., e will have to fall).

[1] The case for which $\beta = \infty$, is the Dornbusch case. In that case our equation (14) coincides with equation (6) in Dornbusch (1976, p. 1164).

The reduction in e serves to restore equilibrium by worsening the trade balance and by creating expectations of currency depreciation and, thereby, worsening the capital account. In this case, the exchange rate and the price level move in opposite directions. If, on the other hand, the speed of adjustment in asset markets is low (or more precisely, if β is low relative to δ/b), the deterioration of the trade balance following the rise in the price level would outweigh the improvement in the capital account, and balance of payments equilibrium would require a depreciation of the currency, i.e., a rise in the exchange rate. In that case the dynamics of adjustment is characterized by a situation in which prices and exchange rates move in the same direction.

II.5 The Effect of Monetary Expansion: Overshooting and Undershooting

In the previous section we characterized the relationship between the exchange rate, the price level and the speed of asset market adjustment. This relationship can be illustrated with the aid of Figures 1 and 2 which will then be used to analyze the effects of monetary changes. In these figures, the $\dot{p} = 0$ schedule shows a combination of exchange rates and price levels for which there is no excess demand for domestic output. The schedule plots equation (6) and its slope is unity.[1] The intercept of the schedule corresponds to the (logarithm of the) equilibrium long-run real exchange rate k. Also, along this schedule the balance of trade must be balanced so that T=0. All points to the right of the $\dot{p} = 0$ locus correspond to an excess demand for goods and to a trade balance surplus. Consider next the schedule along which the capital account is balanced. From (13), the capital account can be written as

[1] The $\dot{p} = 0$ schedule would be flatter than a 45° line if the demand for goods were to depend negatively on the rate of interest as in Dornbusch (1976). In that case a rise in the price level lowers the demand via the higher relative price and via the rate of interest that must be higher in order to restore money market equilibrium.

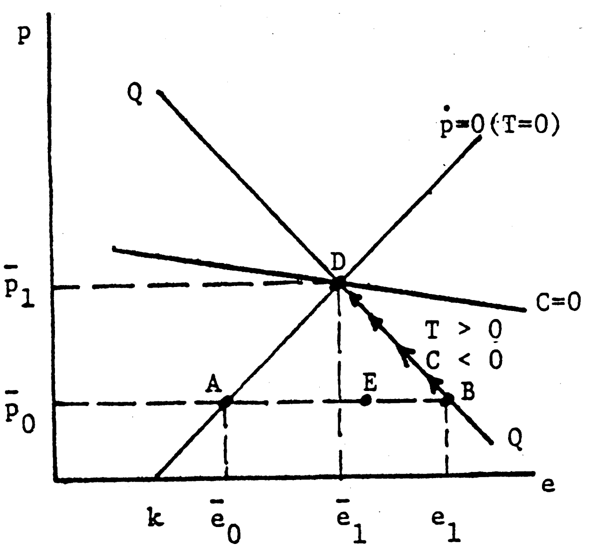

Figure 1: High Capital Mobility
$\beta > \delta/b$

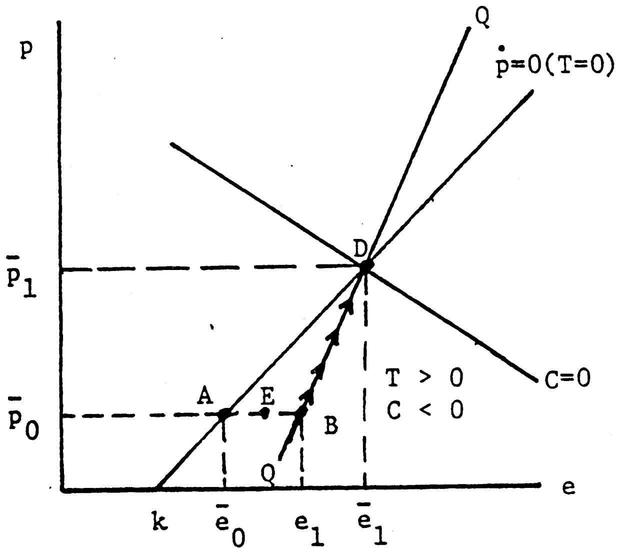

Figure 2: Low Capital Mobility
$\beta < \delta/b$

$$C = \beta[b(p - \bar{p}) - \theta(\bar{e} - e)] \quad .$$

Thus, the slope of the schedule along which the capital account is balanced (C=0) is $-\theta/b < 0$ as is shown in Figures 1 and 2. Points below the C=0 schedule correspond to a deficit in the capital account.

The equilibrium relationship between the price level and the exchange rate (which must hold at each moment of time) is summarized by equation (14) that is plotted as the QQ schedule in Figures 1 and 2. The slope of the schedule is $1/\varepsilon$ which may be positive or negative depending on the sign of ε which in turn depends on whether β is smaller or larger than δ/b. When the degree of capital mobility is low, $\beta < \delta/b$ and the slope of the schedule is positive and larger than unity since $\varepsilon < 1$. When asset markets adjust relatively fast, the QQ schedule is negatively sloped. Since along the equilibrium path the balance of payments is balanced, the QQ schedule must pass in a region which is characterized by a surplus in the balance of trade and a deficit in the capital account ($T > 0$, $C < 0$) or by a deficit in the balance of trade and a surplus in the capital account ($T < 0$, $C > 0$). Thus, when the QQ schedule is negatively sloped as in Figure 1, it must be steeper than the C=0 locus.[1]

Consider point B in Figures 1 and 2. At this point, there is an excess demand for goods and $\dot{p} > 0$. Also at point B there is a trade balance surplus ($T > 0$) and a capital account deficit ($C < 0$). The path of adjustment is described by the arrows along the equilibrium schedule QQ and long-run equilibrium is reached at point D where prices and exchange rates reach their equilibrium values $\bar{p}_1$ and $\bar{e}_1$. At this point expected depreciation of the currency is zero, domestic and foreign rates of interest are equalized so that the capital account is balanced and goods market clear so that $\dot{p} = 0$

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[1]The slopes of the two schedules coincide when $\beta=\infty$.

and the balance of trade is balanced. As is evident, in this model the trade balance and the capital account play a symmetric role in determining the equilibrium exchange rate. It may not be aruged therefore that the exchange rate is determined exclusively in asset markets and not in the commodity markets. In the extreme case, however, when $\beta=\infty$, like in Dornbusch's model (1976), this dichotomy does exist. The exchange rate is determined at that level that ensures that the rates of return on domestic and foreign securities are equalized at each instant so as to satisfy equation (7). The size of the capital account in turn is determined by the balance of trade so as to ensure equilibrium in the balance of payments.

To analyze the effects of a monetary expansion, consider an initial long-run equilibrium at point A with $\bar{p}_0$ and $\bar{e}_0$ as the corresponding price level and exchange rate. Through point A passes a QQ schedule (not drawn) which corresponds to the initial quantity of money. A rise in the money supply raises the long-run equilibrium values of prices and the exchange rate equiproportionally to $\bar{p}_1$ and $\bar{e}_1$ and thus moves the long-run equilibrium combination from point A to point D. The initial QQ schedule moves to the right to the position that is drawn in Figures 1 and 2. Upon the change in the money supply the price level is given at its initial value $\bar{p}_0$. Equilibrium in the balance of payments requires that the exchange rate jumps immediately to e_1 and the short-run equilibrium is attained at point B. As may be seen, when the speed of adjustment in asset markets is relatively high, the exchange rate overshoots its equilibrium long-run value (as in Figure 1) while when the speed of adjustment is relatively low, the exchange rate undershoots its long-run equilibrium value (as in Figure 2).

The impact effect of the monetary change can be analyzed in terms of equation (14). By the homogeneity postulate $dm = d\bar{e} = d\bar{p}$ and thus, given the price level, the short-run elasticity of the exchange rate with respect to the money supply is:

(15) $$\frac{de}{dm} = 1 - \varepsilon ,$$

and substituting (14) for ε, the elasticity can be written as

(15') $$\frac{de}{dm} = 1 - \frac{\delta - \beta b}{\delta + \beta\theta} \gtrless 1 .$$

When the speed of adjustment is relatively high so that $\beta > \delta/b$, $\varepsilon < 0$ and the short-run elasticity exceeds unity as in Figure 1. This is the overshooting phenomenon that corresponds to the Dornbusch case. On the other hand, when the speed of adjustment is relatively low so that $\beta < \delta/b$, ε is positive but smaller than unity, the short-run elasticity is smaller than unity and the exchange rate undershoots its new long-run equilibrium value. In the border case for which $\beta = \delta/b$, the QQ schedule is vertical and the exchange rate reaches immediately its long-run value as e_1 coincides with $\bar{e}_1$. It may also be noted that the extent of overshooting or undershooting depends on the magnitude of θ--the speed of adjustment of expectations, the determinants of which are analyzed below. As is clear from equation (15'), other things equal, the short-run elasticity gets closer to unity as the value of θ increases and, thereby, reducing the extent to which the current exchange rate differs from its long-run value. It is also evident that as long as θ is not negative its magnitude is irrelevant for determining whether the short-run elasticity is larger or smaller than unity and, therefore, the analysis is consistent with a variety of assumptions concerning the formation of expectations ranging from the assumption of static expectations (for which $\theta=0$), to the assumption of perfect foresight which is analyzed below.

As is evident, the key factor determining whether the exchange rate overshoots or undershoots its long-run equilibrium value is the relationship between β and δ/b. These parameters characterize the speed of adjustment in asset markets, the sensitivity of aggregate demand (the balance of trade) to relative prices and the interest (semi) elasticity of the demand for money. As long as the speeds of adjustment are finite, the speed of commodity price adjustment, π, does not determine whether or not there is overshooting.

Turning to the effect of the monetary expansion on the international accounts, we note that, at point B, independent of whether the exchange rate overshoorts or undershoots, the rise in e improves the balance of trade and the rise in m deteriorates the capital account by lowering the rate of interest. The deterioration in the capital account due to the interest rate effect is mitigated when the exchange rate overshoots its long-run equilibrium value since, in that case, expectations are for an appreciation of the currency (a decline in e). In the case of undershooting the expectations for a further depreciation reinforce the interest rate effect in deteriorating the capital account. The transition towards the long-run (the path between points B and D), is characterized by a rising price level and by a decline in the <u>real</u> exchange rate. The decline in $(e - p)$ results in a deterioration of the balance of trade and, therefore, equilibrium in the balance of payments implies that during the transition, the capital account improves.

The above analysis implies that the qualitative characteristics of the dynamics of the price level, the trade balance and the capital account are independent of whether there is overshooting or undershooting of the exchange rate. These given qualitative paths may be associated with a path along which the exchange rate is rising, as well as with a path along which the exchange rate is falling. The ambiguous relationship between the path of the exchange rate and the other paths should not be taken to imply that the exchange rate does not exert a definite effect on the trade balance, the capital account and on the path of prices. Rather, it implies that one should not expect to observe, independent of the speed of adjustment, a unique qualitative relationship between the equilibrium paths of the exchange rate and those of prices and the international accounts. This lack of a unique general relationship between the exchange rate and the various balance of payments accounts may be responsible for the view that in recent years exchange rates have shown erratic and unpredictable movements.[1]

In this section we analyzed the effects of a once and for all unanticipated change in the money supply. The analysis can be easily extended to examine the effects of other parametric changes like changes in output, the foreign price level and the foreign rate of interest. Similarly, the analysis can be extended along the lines suggested by Wilson (1978) to examine the effects of an anticipated future change in the supply of money or in another parameter. For example, it can be shown that an anticipated future rise in the money supply induces an immediate adjustment of the exchange rate which jumps, for example, to point E in Figures 1 and 2. The extent of the instantaneous jump in the exchange rate is smaller than the change that would have taken place had the money supply been expected to rise at the present (in which case the exchange rate would have adjusted to point B). Following the initial jump in e, both the exchange rate and prices proceed to rise gradually and their path converges to the new QQ schedule (corresponding to the new quantity of money) at the point in time at which the rise in the money supply actually occurs. Thereafter the convergence proceeds along the (new) QQ schedule towards the new long-run equilibrium.[2]

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[1]The relationship between the exchange rate and the trade balance is analyzed in detail in many recent contributions. See, for example, Kouri (1976), Branson (1977), Dornbusch and Fischer (1980), Mussa (1980b) and Rodriguez (1980).

[2]It follows that when capital is highly mobile so that the QQ schedule is negatively sloped, the path of prices will be monotonic while the path of the exchange rate will exhibit a turning point, i.e., e will initially rise and then decline; when capital is less mobile so that the QQ schedule is positively sloped, both prices and the exchange rate will approach their new higher values monotonically.

II.6 Perfect Foresight and the Coefficient of Expectations

So far it was assumed (in equation (8)) that the expected percentage change in the exchange rate is proportional to the discrepancy $(\bar{e} - e)$ with $\theta > 0$ being the proportionality factor. Dornbusch (1976) showed that in a model of perfect foresight, the coefficient θ cannot be chosen arbitrarily but rather, it must be consistent with the structure of the entire model. We turn now to an analysis of the determinants of the coefficient of expectations in our model.

Using equation (12) in (6), we may express the rate of inflation as

$$\dot{p} = \alpha[(e - \bar{e}) - (p - \bar{p})], \tag{16}$$

and using equation (14), the rate of inflation can be written as:

$$\dot{p} = \alpha(1 - \frac{1}{\varepsilon})(e - \bar{e}). \tag{17}$$

The relationship between the equilibrium exchange rate and the price level that is described by equation (14), must be always satisfied. Therefore, given the long-run values of $\bar{e}$ and $\bar{p}$, changes in the exchange rate and in the price level must be related such that

$$\dot{e} = \varepsilon\dot{p}. \tag{18}$$

Substituting equation (17) for $\dot{p}$, we obtain

$$\dot{e} = \alpha(1 - \varepsilon)(\bar{e} - e). \tag{19}$$

Equation (19) describes the <u>actual</u> change in the exchange rate while equation (8) describes the <u>expected</u> change. It is clear that, under perfect foresight, consistency requires that the two are equal to each other and, therefore,

$$\theta = \alpha(1 - \varepsilon). \tag{20}$$

Substituting for ε from (14) results in

$$\theta = \alpha[1 - \frac{\delta - \beta b}{\delta + \beta\theta}] \quad , \tag{21}$$

from which it follows that the coefficient of expectations can be obtained by solving the quadratic equation

$$(22) \qquad \theta^2 + \left(\frac{\delta - \alpha\beta}{\beta}\right)\theta - \alpha b = 0 \quad .$$

From (22) the solution for θ (obtained by taking the positive root) is

$$(23) \qquad \theta = -\frac{1}{2}\left[\left(\frac{\delta - \alpha\beta}{\beta}\right) - \left\{\left(\frac{\delta - \alpha\beta}{\beta}\right)^2 + 4\alpha b\right\}^{1/2}\right] > 0$$

which expresses the coefficient of expectations as a function of the various parameters of the model.

As may be verified, the coefficient of expectations decreases with $1/b$, the interest (semi) elasticity of the demand for money, while it increases with π and β, the speeds of adjustment in goods and asset markets, respectively. These propositions are independent of the degree of capital mobility. In contrast, however, it is noteworthy that the dependence of the coefficient of expectations on the parameter δ (the sensitivity of aggregate demand to relative prices) is ambiguous and depends on whether $\pi\beta$--the product of the speeds of adjustment in goods and asset markets--is smaller or larger than unity. For a given value of π, a high value of β such that $\pi\beta > 1$, yields a positive relationship between the coefficient of expectations and the parameter δ. On the other hand, when β is small such that $\pi\beta < 1$, a high value of δ reduces the size of the coefficient of expectations. Since the relationship between the speed of adjustment of expectations and δ is ambiguous, it follows that the effect of a higher value of δ on the extent of the overshooting or undershooting is also ambiguous. Finally, it might be noted that in the extreme case for which asset markets clear instantaneously so that $\beta = \infty$, equation (21) becomes

$$(21') \qquad \theta = \alpha(1 + b/\theta)$$

which corresponds to equation (14) in Dornbusch (1976, p. 1167) and, as noted above, in that case δ and θ are positively related.

In this section we analyzed the dynamics of exchange rates within a rational expectations model in which commodity prices adjust slowly. The analysis was based on a modified version of a model due to Dornbusch (1976). We modified the model so as to allow for a finite speed of adjustment in asset markets and we showed that the short-run effects of a monetary expansion depend on the degree of capital mobility. When capital is highly mobile the exchange rate must overshoot its long-run value[1] but when capital is relatively immobile the exchange rate undershoots its long-run value. The key reason for the non-neutrality of money in the short run in this model arises from the assumption that prices are not fully flexible. In the next section we analyze the dynamics of exchange rates in a portfolio-balance model in which all prices are assumed to be fully flexible also in the short run.

III. Exchange Rate Dynamics and Portfolio Balance

In this section we analyze the dynamics of exchange rates and the overshooting hypothesis within the context of a portfolio-balance model. Developments of various varieties of the portfolio-balance model which emphasize the effects of asset substitution on exchange rate determination are the subject of numerous recent articles [e.g., Kouri (1976), Branson (1979), Dornbusch (1978) and the references therein]. Our purpose is to highlight the implications of alternative assumptions concerning the degree of substitution among assets on the dynamics of exchange rates. It will be shown

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[1]This conclusion is based on the assumption that output is fixed. Dornbusch shows that when the monetary expansion induces a short-run rise in output the exchange rate may undershoot its equilibrium level even if capital is highly mobile. This will occur if the rise in output raises the demand for money sufficiently so as to result in a rise in the rate of interest.

that the effects of monetary expansion on the dynamics of exchange rates and in particular on whether exchange rates overshoot or undershoot their equilibrium path depend critically on the specification of asset choice. In order to contrast the analysis with the one in the previous section, we will assume that goods markets clear instantaneously and that all prices are perfectly flexible. We start with a brief review of the currency substitution model developed by Calvo and Rodriguez (1977).

III.1 The Currency Substitution Model

The Calvo-Rodriguez model of currency substitution analyzes a fully employed small open economy in which residents are assumed to hold portfolios of domestic and foreign currencies. The key building blocks of the model are the specifications of the markets for assets and goods.

III.1.1 The Assets Market

Asset holders are assumed to hold portfolios of domestic money, M, and foreign money, F. The value of assets in terms of foreign currency is denoted by a

(24) $$a = M' + F$$

where M' denotes the value of domestic currency holdings in terms of foreign exchange, i.e., $M' \equiv M/S$.

The desired ratio of domestic to foreign money holdings is assumed to depend on the expected percentage change in the exchange rate which measures the expected difference between the rates of return on the two assets. The assumption of rational expectations (which in this model amounts to perfect foresight) permits us to identify the expected change in the exchange rate with the actual change. Using a circumflex (^) to denote the percentage change in a variable, portfolio equilibrium can be written as

$$(25) \qquad \frac{M'}{F} = L(\hat{S}); \quad L' < 0$$

which indicates that the desired ratio of domestic to foreign money declines when the domestic currency is expected to depreciate. It will prove useful to express the portfolio-balance relationship in terms of its inverse as in equation (25')

$$(25') \qquad \hat{S} = \ell(M'/F); \quad \ell' < 0.$$

III.1.2 <u>The Goods Market</u>

The economy is assumed to produce two classes of goods: tradeable and non-tradeable goods. For a given state of technology and factor endowment, the rates of production of the two composite commodities depend on their relative price. Denoting the domestic currency price of traded goods by P_T and of non-traded goods by P_N, the relative price that is relevant for production decisions is P_T/P_N. The domestic price of traded goods is linked to the foreign price of that good, P_T^*, through international arbitrage so that $P_T = SP_T^*$. The small country is assumed to face a given foreign price of traded goods which, for convenience, is normalized to unity. Thus, the relative price which governs the allocation of productive resources can be written as $s \equiv S/P_N$--the "real exchange rate," and the output of the two goods can be specified as

$$(26) \qquad \begin{aligned} Q_T &= Q_T(s); \quad \partial Q_T/\partial s > 0 \\ Q_N &= Q_N(s); \quad \partial Q_N/\partial s < 0 \end{aligned}$$

where Q_T and Q_N denote, respectively, the output of traded and non-traded goods.

The demand for the two goods is assumed to depend on their relative price and on the value of assets according to

$$C_T = C_T(s,a); \quad \partial C_T/\partial s < 0, \ \partial C_T/\partial a > 0$$

(27)

$$C_N = C_N(s,a); \quad \partial C_N/\partial s > 0, \ \partial C_N/\partial a > 0$$

where C_T and C_N denote, respectively, the demand for traded and non-traded goods.

At each point in time the stock of domestic holdings of foreign assets, F, is given, and the assumption that the small country's currency is not held by foreigners ensures that F cannot be adjusted instantaneously. Asset holders can, however, alter the stock of foreign assets gradually by running a surplus or a deficit in the balance of trade. Thus,

(28) $$Q_T(s) - C_T(s,a) = \dot{F}$$

where $\dot{F} \equiv dF/dt$ denotes the rate of change in F. Equilibrium in the market for non-traded goods requires that the rate of domestic production equals the domestic demand so that

(29) $$Q_N(s) - C_N(s,a) = 0 \ .$$

Equation (29) implies that there is a specific relationship between the real exchange rate and the value of assets that is consistent with equilibrium in the market for non-traded goods. A rise in the value of assets must be accompanied by a decline in the real exchange rate since the former creates an excess demand for non-traded goods while the latter induces an excess supply. This relationship is summarized by equation (30).

(30) $$s = s(a); \quad s' < 0 \ .$$

Since equation (30) must hold at each moment of time due to the assumed flexibility of prices, it can be substituted into equation (28) in order to yield a relationship between the rate of change in F and the value of assets:

(31) $$\dot{F} = f(a); \quad f' \equiv \left(\frac{\partial Q_T}{\partial s} - \frac{\partial C_T}{\partial s}\right)s' - \frac{\partial C_T}{\partial a} < 0 \ .$$

The value of assets is related uniquely to the equilibrium real exchange rate and thereby to the rates of production and consumption of goods and to the rate of accumulation of foreign currency. Therefore, knowledge of the time path of assets is necessary for determining the time path of these variables. We turn now to study the evolution of asset holdings.

III.1.3 Dynamics

Changes in asset holdings arise from changes in the domestic and the foreign asset components of the portfolio:

$$\dot{a} = \dot{M}' + \dot{F} . \tag{32}$$

Recalling that $M' = M/S$, it follows that $\dot{M}' = M'(\mu - \hat{S})$ where μ denotes the percentage change in the nominal money supply, i.e., $\mu \equiv \dot{M}/M$. Since $M' = a - F$, we can express the change in M' as $M' = (a - F)(\mu - \hat{S})$. Thus, equation (32) can be written as

$$\dot{a} = (a - F)[\mu - \ell(\frac{a - F}{F})] + f(a) \tag{33}$$

where, using equations (25') and (31), $\ell(\frac{a - F}{F})$ was substituted for $\hat{S}$ and $f(a)$ was substituted for $\dot{F}$.

Equations (31) and (33) characterize the dynamics of the system. As is clear, in the steady state when $\dot{F} = \dot{a} = 0$, $f(a) = 0$ (equation (31)) and $\mu = \hat{S}$ (equation (33)). We denote the steady state values of a and F by $\bar{a}$ and $\bar{F}$ and, using equation (30), the implied steady state real exchange rate is denoted by $\bar{s}$. It is also noteworthy that the system satisfies the homogeneity postulate: a once-and-for-all rise in the nominal quantity of money results in an instantaneous equiproportional rise in the money price of non-traded goods and in the nominal exchange rate (and thereby in the money price of traded goods). These changes leave all real variables (including the real exchange rate) unchanged. In contrast with the discussion in section II where due to the assumed slow price adjustment a once-and-for-all change in the nominal quantity of money exerted real effects (by inducing in the short run a rise in the real quantity of money), the flexibility of prices which is assumed in the present section rules out such effects. In the present model, however, changes in the percentage rate of growth of the money supply are not neutral in the long run and do result in a gradual transition period.

Figure 3 describes the dynamics of the system. In Panel I the $\dot{F} = 0$ and the $\dot{a} = 0$ schedules describe combinations of a and F which satisfy equations (31) and (33) respectively. The slope of the $\dot{a} = 0$ schedule is drawn on the assumption that (around the steady state) $\partial\dot{a}/\partial a < 0$. As is evident, the system exhibits a saddle-path stability, and the motion of the variables is described by the arrows which are implied by the signs of the partial derivatives of (31) and (33) around the steady state. None of the qualitative conclusions are altered in the case for which $\partial\dot{a}/\partial a > 0$. In that case the $\dot{a} = 0$ schedule is positively sloped and is steeper than the saddle path. In general, along the perfect foresight path (which is the unique path that converges to the steady state and satisfies the laws of motion and the initial conditions) a higher value of F is associated with a higher value of a. Panel II in Figure 3 presents the combinations of the value of assets and the real exchange rate which satisfy equation (30). These are the combinations that are consistent with equilibrium in the non-traded goods market for which a rise in the value of assets must be associated with a decline in s.

Consider a rise in the rate of monetary expansion. From equation (33) it is seen that the higher value of μ shifts the $\dot{a} = 0$ schedule and hence the saddle path to the right, and results in new higher steady state holdings of

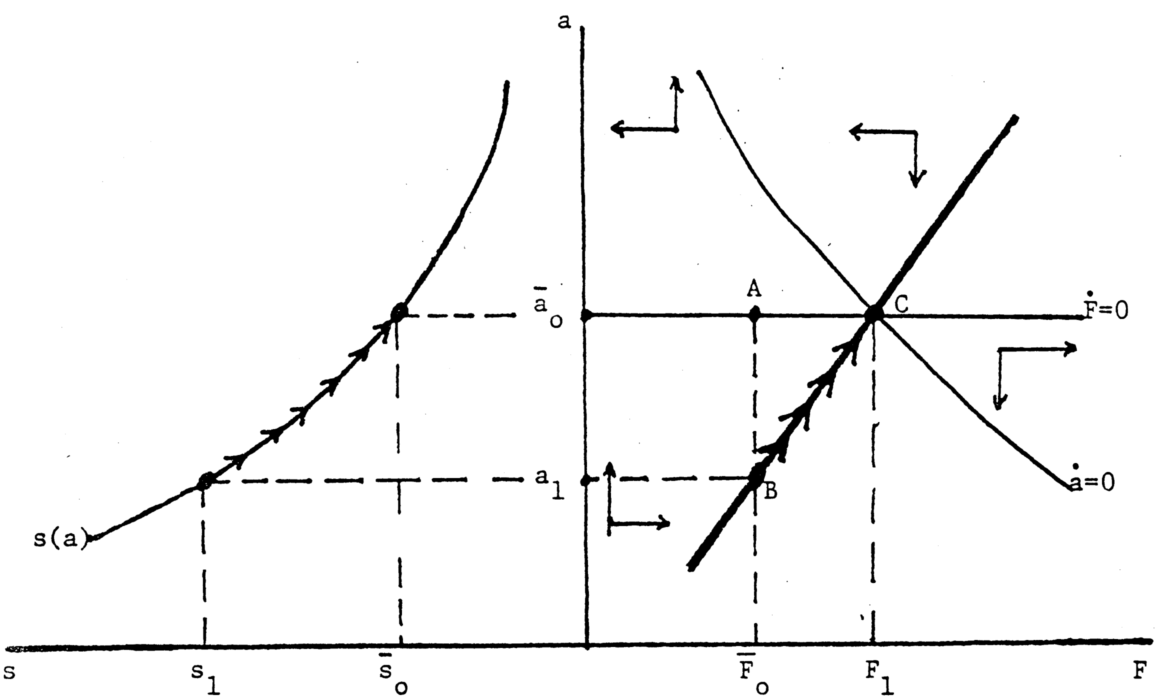

Figure 3: Exchange Rate Dynamics in the Currency Substitution Model

foreign assets. In the new steady state the real value of assets remains unchanged so as to ensure that $\dot{F} = 0$ (equation (31)). Since the equilibrium real exchange rate is uniquely related to the value of assets, also the steady state real exchange rate remains unchanged and thus, production and consumption of both goods remains unchanged. Finally, since in the new steady state the new rate of monetary expansion equals the rate of depreciation $\hat{S}$, individuals will lower the desired ratio of domestic to foreign currency holdings which, given the unchanged value of assets implies that F rises and M' falls.

The dynamics of adjustment is shown in Figure 3 where it is assumed that the initial steady state position was at point A with $\bar{F}_o$, $\bar{a}_o$ and $\bar{s}_o$ as the initial equilibrium values, foreign currency holdings, total assets and the real exchange rate, respectively. The schedules that are drawn correspond to the new higher rate of monetary expansion. Upon the rise in μ the instantaneous equilibrium jumps to point B along the new saddle path. Since F cannot change instantaneously, point B is the only position of short-run equilibrium that is consistent with the perfect foresight path that converges to the new steady state. At point B the value of assets falls from $\bar{a}_o$ to a_1. This decline in the value of assets is necessary since the rise in the expected relative cost of holding domestic money induces a reduction in the desired ratio of domestic to foreign monies which, given the initial value of foreign currency holdings $\bar{F}_o$, can be brought about by a decline in M' and thus in a. Since at the initial point in time the nominal stock of domestic money M is given, the decline in $M' \equiv M/S$ is brought about through a rise in the nominal exchange rate S (i.e., through a depreciation of the domestic currency). Finally, as indicated in panel II of Figure 3, equilibrium in the non-traded goods market implies that when the value of assets falls to a_1 the real exchange rate rises to s_1. Since the real exchange rate is the ratio of the nominal exchange rate S to the price of non-traded goods P_N, it follows that $\hat{S} > \hat{P}_N$. If the aggregate price level is a weighted average of S and P_N, it follows that the exchange rate changes by more than the overall price level. This is the overshooting phenomenon in the Calvo-Rodriguez model.

The transition towards the new steady state is characterized by the path between B and C along which s declines (so that $\hat{S} < \hat{P}_N$), the value of assets rises as does the value of foreign currency holdings. The model implies that during the transition period a higher depreciation of the currency is associated with a trade balance surplus and an accumulation of foreign assets. This characteristic is typical of the currency substitution model, reflecting the desired change in the composition of assets.

The key feature of the Calvo-Rodriguez model is the specification of the portfolio of assets where it is assumed that the two alternative assets are domestic and foreign currencies. Since the foreign currency price of traded goods is assumed to be given, the accumulation of foreign currency is equivalent to an accumulation of claims on stocks of traded goods. With this perspective the currency substitution model can be specified in terms of choice and substitution between domestic money and traded goods. It is intuitively clear therefore that following the rise in the rate of monetary expansion asset holders wish to hedge against the expected inflation by shifting the composition of portfolios towards the inflation hedge (traded goods), a shift which results, in the short run, in a rise in s--the relative price of traded goods.

This interpretation of the currency substitution model suggests that when the inflation hedges are stocks of non-traded goods instead of traded goods, the rise in the rate of monetary expansion might result in an undershooting of the exchange rate as the relative price of non-traded goods rise. We turn now to the formal analysis of this possibility.

III.2 Non-Traded Goods as the Inflation Hedge

The structure of the model in which non-traded goods are used as the inflation hedge is very similar to the one described in section III.1. In what follows we introduce the minimal modifications.

III.2.1 The Asset Market

In order to sharpen the contrast with the currency substitution model we assume that the portfolios of assets are composed only of domestic money and of stocks of non-traded goods which are denoted by N. The value of assets in terms of foreign exchange is

$$a = M' + N/s \tag{34}$$

where $N/s = P_N N/S$. As before, the desired ratio of money to inventories of goods is assumed to depend on the difference between their rates of return, i.e., on the expected percentage change in the price of non-traded goods. Assuming that expectations are always realized the desired portfolio composition depends on $\hat{P}_N$, and analogously to equation (26) the portfolio-balance relationship can be written as

$$\hat{P}_N = g\left(\frac{M'}{N/s}\right); \quad g' < 0 \tag{35}$$

III.2.2 The Goods Market

The specification of production and consumption is assumed to be the same as in the previous section and is summarized by equations (26) and (27). In the present case, however, we allow for an accumulation of inventories of non-traded goods which must equal the excess of production over consumption of these goods.

(36) $Q_N(s) - C_N(s,a) = \dot{N}$

where $\dot{N}$ denotes the rate of accumulation of non-traded goods.

Since in this case we do not allow for capital mobility, equilibrium in the market for traded goods requires that

(37) $Q_T(s) - C_T(s,a) = 0$.

Equation (37) implies that there is a specific relationship between the real exchange rate and the value of assets which guarantees trade balance equilibrium. A rise in the value of assets raises the demand for traded goods and therefore, to eliminate the excess demand, it must be accompanied by a rise in the real exchange rate s. This relationship which must be satisfied at all times can be written as

(38) $s = v(a); \; v' > 0$.

For later use we note that

(38') $\hat{s} = \varepsilon\hat{a}$

where ε denotes the elasticity of the real exchange rate with respect to the value of assets. Substituting equation (38) into (36) yields a relationship between the rate of accumulation of non-traded goods and the value of assets:

(39) $\dot{N} = h(a); \quad h' \equiv \left(\frac{\partial Q_N}{\partial s} - \frac{\partial C_N}{\partial s}\right)v' - \frac{\partial C_N}{\partial a} < 0$.

III.2.3 Dynamics

The rate of change in the value of assets can be written, using equation (34) as

(40) $\dot{a} = M'\hat{M'} + N/s(\widehat{N/s})$.

Noting that

$$P_N = \frac{M}{(M/S)(S/P_N)} ,$$

it follows that $\hat{P}_N = \mu - \hat{M}' - \hat{s}$, and using equation (35) yields

$$\text{(41)} \qquad \hat{M}' = \mu - g(\frac{v(a)a}{N} - 1) - \varepsilon\hat{a}$$

where $(v(a)a/N) - 1$ was substituted for $M'/(N/s)$ by using equations (34) and (38) and where $\varepsilon\hat{a}$ was substituted for $\hat{s}$ by using equation (38').

Using equations (39) and (41) in (40) yields

$$\text{(42)} \qquad \dot{a} = \frac{1}{1+\varepsilon}[(a - \frac{N}{s})[\mu - g(\frac{v(a)a}{N} - 1)] + \frac{h(a)}{v(a)}] .$$

Equations (39) and (42) characterize the dynamics of the system. In the steady state $\dot{N} = \dot{a} = 0$, the value of assets is $\bar{a}_o$, the holdings of non-traded goods is $\bar{N}_o$ and the rate of monetary expansion μ equals $g(\cdot)$--the rate of change of the price of non-traded goods $\hat{P}_N$. Equilibrium in the balance of trade implies that $\bar{a}_o$ is associated with a specific steady state real exchange rate $\bar{s}_o$. Since in the steady state the percentage change in the nominal price of non-traded goods equals the rate of monetary expansion and since the real exchange rate is given at $\bar{s}_o$, the percentage change in the nominal exchange rate S must also equal the rate of monetary expansion.

The dynamics of the system is described in Figure 4. In panel I the $\dot{N} = 0$ and the $\dot{a} = 0$ schedules show combinations of a and N which satisfy equations (39) and (42) respectively. The slope of the $\dot{a} = 0$ schedule is drawn on the assumption that around the steady state $\partial\dot{a}/\partial a < 0$. As in section III.1 the system exhibits a saddle path stability and the motion of the variables is described by the arrows which reflect the signs of the partial derivatives of (39) and (42) around the steady state. When $\partial\dot{a}/\partial a > 0$, the $\dot{a} = 0$ schedule is positively sloped and is steeper than the saddle path. As

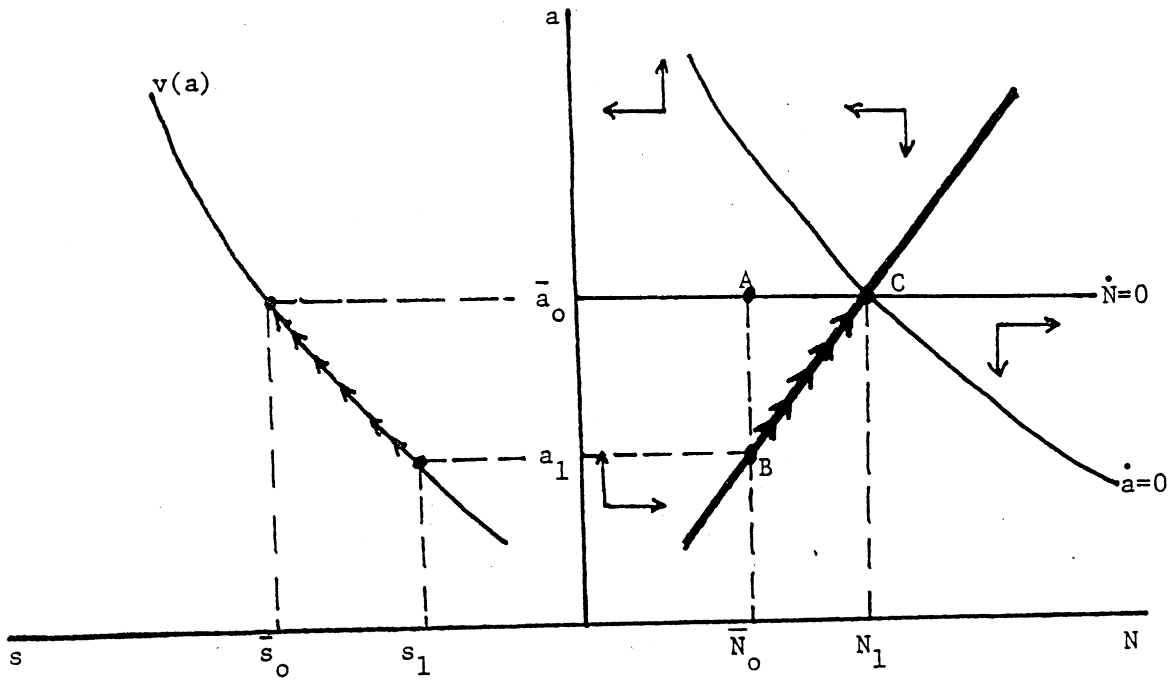

Figure 4: Exchange Rate Dynamics When Portfolios Contain Money and Non-Traded Goods

before, none of the qualitative conclusions are altered in that case. The key difference between the analysis in Figure 4 and that in Figure 3 lies in panel II which shows the equilibrium relationship between the real exchange rate and the value of assets. In contrast with the currency substitution model, here s and a must be positively related so as to ensure trade balance equilibrium (equation (37)).

A rise in the rate of monetary expansion results (from equation (42)) in a rightward shift of the $\dot{a} = 0$ schedule and hence of the saddle path. The new steady state is associated with larger holdings of non-traded goods whose attractiveness has risen with the accelerated inflation. Suppose that the initial equilibrium is described in Figure 4 by point A and that the schedules drawn correspond to the new higher rate of monetary expansion. Since at the initial point in time the stocks of non-traded goods are given at $\bar{N}_o$, the instantaneous equilibrium is reached at point B with a lower value of assets a_1. The reduced value of assets lowers the demand for traded goods and therefore, to restore trade balance equilibrium, the real exchange rate must fall to s_1 as indicated in panel II.

The higher expected rate of inflation lowers the desired ratio of money to inventories of non-traded goods $\frac{M'}{N/s} = M/P_N N$. At the initial moment the quantities of M and N are given, and the desired ratio is attained therefore through a rise in P_N. Since, however, the value of assets declined and since N/s rose, it follows that the nominal exchange rate S must have risen (i.e., the domestic currency must have depreciated) so as to yield a decline in $M' = M/S$. The rise in S must be sufficiently large so as to more than offset the effect of the rise in N/s on the value of assets. While both the nominal exchange rate S and the price of non-traded goods P_N jump up upon the rise in the rate of monetary expansion, the fact that the real exchange rate falls to s_1' implies that $\hat{P}_N > \hat{S}$. Thus, in this model the exchange rate undershoots the price level.

The transition towards the steady state is described by the path from B to C along which the value of assets and the holdings of non-traded goods increase and the real exchange rate rises towards its initial level. Since along the path s rises, the nominal exchange rate must rise faster than the price of non-traded goods.

The fact that the rise in the rate of monetary expansion results in an instantaneous rise in the price level which exceeds the rise in the depreciation of the currency is consistent with the general principles that were outlined at the end of the discussion of the currency substitution model. In this class of the portfolio-balance model the key factor determining whether following a monetary disturbance the exchange rate overshoots or undershoots the domestic price level is the specification of the inflation hedge. When the domestic rate of inflation accelerates asset holders substitute away from domestic money into alternative assets. To the extent that the alternative assets are traded goods, their relative price will rise and the nominal exchange rate will overshoot the domestic price level. To the extent that the alternative assets are domestic non-traded goods, their relative price will rise and the exchange rate will undershoot the domestic price.

In this section we analyzed the two polar cases in which the substitutes for domestic money were either foreign currency (or equivalently traded goods) or stocks of domestic non-traded goods. A more general model would allow for portfolios which consist of domestic and foreign monies as well as of domestic goods. The general principles, however, are likely to be the same. Whether exchange rates overshoot or undershoot the domestic price level will depend on the relative degree of substitution between domestic and non-traded goods. The relative degrees of substitution will reflect the degree of capital mobility and the qualities of the various assets as hedges against inflation.

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