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Exchange Rate Dynamics, Sticky Prices and the Current Account

1. INTRODUCTION

RATIONAL EXPECTATIONS EXCHANGE RATE MODELS have been of two principal types—flexible price models and sticky price models. The flexible price models may be further divided into those where current-account-based wealth effects are an important driving force in exchange rate dynamics and those where such effects are ignored.[1] Notably, the literature includes few sticky price models incorporating current-account-based wealth effects.[2]

Two reasons for the scarcity of such models are (a) the belief that current-account-based wealth effects are empirically unimportant for exchange rates and (b) that a model endogenizing exchange rate movements, sticky price movements, and current-account-based wealth effects is relatively difficult to analyze. We note though that recent empirical work (e.g., Meese and Rogoff 1983) has called into question the empirical importance of the standard determinants of exchange rates. Consequently the criterion of empirical relevance has not yet distinguished among models of exchange rates. In connection with reason (b), note that a rational expectations, sticky price exchange rate model, where current-account-based wealth

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[1]The early contributions to the flexible price exchange rate literature are those of Frenkel (1976) and Mussa (1976), who ignore current-account-based wealth effects, and Kouri (1976), who incorporates such effects. Dornbusch (1976) provided the seminal contribution to the sticky price literature.

[2]Complete rational expectations—price models where current-account-based wealth effects are important—are provided by Eaton and Turnovsky (1983), Calvo (1982), Mussa (1982b), Kind (1982), and Driskill and McCafferty (1983). Dornbusch and Fischer (1980) develop such a model with static expectations and Rodriguez (1979) develops a model where price is fixed indefinitely.

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effects are important, involves the exchange rate, domestic prices, net international indebtedness, and expected future values of all of these variables. The typical formulation of such a model becomes a third-order dynamic system. The difficulties involved in solving such a system are well known.

Despite such difficulties, our intention in this paper is to present and analyze an exchange rate model incorporating sticky prices and current-account-based wealth effects. We see two ways to proceed. The first way is to "grit our teeth" and work through the difficult analytics of the third-order system. The second method is to make some simplifications, reducing the complexity of solutions while recognizing that such simplifications reduce the richness of the final results. Our method in this paper is the second one. We simplify the analysis so that analytical solutions are obtained easily.

One of our assumptions stands out as crucial to our analysis. It involves the speed at which domestic prices are assumed to adjust to disequilibrium in the market for domestic goods. In the typical model, prices are predetermined and adjust slowly to goods market disequilibrium, moving to correct a fraction of disequilibrium each period. Our simplification is to assume that each period domestic prices are set at the level such that domestic markets are expected to clear. When shocks hit the markets, however, the domestic money prices of domestic goods may not adjust immediately and are thus predetermined. Such pricing is a special case of Mussa's (1982a) pricing rule. It appears to preserve essential aspects of sticky price exchange rate models, while reducing the dimension of the dynamic system.

Three results emerge that we consider significant. The first concerns the degree of overshooting of the exchange rate in response to an increase in the money supply originating from an open market purchase of foreign bonds held by domestic residents. Dornbusch (1976) demonstrated that in a world of sticky prices, but where wealth effects are not important, the exchange rate would initially overshoot its long-run level in response to an unexpected monetary change. Overshooting is also a characteristic of the exchange rate response to an open market operation in Kouri's (1976) model. He considers the effects of current-account-induced changes in wealth on money demand and aggregate demand, but in a world of perfectly flexible prices. Paradoxically, we find that allowing a role for wealth in a sticky price model dampens the overshooting of Dornbusch. This curiosity can be explained largely by the fact that under flexible prices the open market operation will have the effect of lowering the real value of domestic wealth, thus lowering money demand, while under sticky prices the open market purchase initially increases real wealth and raises money demand. Under flexible prices the increase in money supply is reinforced by a drop in money demand, but under sticky prices the increase in money supply is partially offset by the jump in demand for money.

The second conclusion is concerned with exchange rate dynamics in a world of sticky prices. A monetary expansion will initially depreciate the real exchange rate (the domestic currency price of foreign goods relative to the domestic currency price of domestic goods), and the nominal rate may overshoot its long-run value. But, the monetary expansion will also increase the real wealth of domestic residents. Initially the depreciation raises the domestic currency value of foreign bonds. There follows a current account surplus, which also serves to increase wealth. As goods prices adjust, the real exchange rate will begin to return to its initial level, and the nominal rate to its new long-run level. But the accumulation of wealth will strengthen the domestic currency. After goods prices have adjusted, the real exchange rate will show an *appreciation* and the nominal rate will lie *below* its long-run value. Only as saving behavior allows adjustment of real wealth in the long run will the monetary change be neutral.

So, these two results tell us that while the exchange rate may not jump as much in response to monetary changes as Dornbusch's model would predict, its adjustment to the long run will not be as smooth.

The third point emphasizes that certain types of sterilized intervention can be effective in temporarily altering exchange rates, even in the presence of uncovered interest parity.[3] If the intervention *ceteris paribus* alters wealth holdings, then the nominal and real exchange rates can change with either sticky or fully flexible goods prices. In the model considered here, such intervention might consist of open market sales of foreign bonds to domestic residents accompanied by direct transfers ("helicopter drops") of money balances so as to leave the aggregate money supply unchanged.

Our exposition is divided into four remaining sections. In section 2 we present our model. In section 3 we give the model's solution when prices are fully flexible. Section 4 does the same for the sticky price model. Some concluding remarks are made in section 5.

2. THE MODEL

In this section we present a model of a medium-sized open economy operating a flexible exchange rate regime. The economy is small in the markets for foreign-produced goods and internationally traded assets. The economy is large in the markets for domestic money and domestically produced goods. Table 1 gives a glossary of notation, and Table 2 lists the principal equations of the model.

Equation (1.1) is the condition that the supply of real money balances, $m_t - p_t$, equals the demand for them, $\alpha_0 - \alpha_1 i_t + \alpha_2(w_t - p_t)$. The demand for money depends negatively on the domestic rate of interest and positively on real wealth. We have adopted the convention of deflating nominal magnitudes by the price of domestic goods rather than by a price index. Equation (1.2) is the condition of uncovered interest parity. The domestic interest rate, i_t, is equal to the foreign rate, i_t^*, plus the expected rate of change of the exchange rate, $E_t s_{t+1} - s_t$. Although our model does not include any bonds issued in units of domestic currency, such bonds if issued would bear interest i_t. Thus, i_t is the opportunity cost of holding domestic money. We assume the foreign interest rate to be a constant, $\bar{i}^*$. Equation (1.3) is our

[3]That such a point is not always recognized is evidenced by, for example, Obstfeld (1982): "Regardless of the exchange rate regime, sterilized intervention may be viewed as an attempt to attain independent exchange rate and money stock targets in the short run. For this to be possible, bonds denominated in different currencies must be imperfect substitutes in private portfolios" (p. 45).

TABLE 1

$b_t^p =$	Logarithm of public holdings of foreign securities at the start of period t—a predetermined variable
$b_t^* =$	Logarithm of public holdings of foreign securities in period t (after open market operations)
$b_t^g =$	Logarithm of central bank holdings of foreign securities
$d_t =$	Logarithm of domestic credit component of money supply
$i_t =$	Level of domestic interest rate
$i_t^* =$	Level of foreign interest rate
$m_t =$	Logarithm of domestic money supply
$p_t =$	Logarithm of domestic currency price of domestically produced goods
$p_t^* =$	Logarithm of foreign currency price of foreign-produced goods
$s_t =$	Logarithm of the exchange rated quoted as domestic currency price of foreign currency
$v_t =$	White noise disturbance to domestic credit component of money supply
$w_t =$	Logarithm of nominal wealth
$y_t =$	Logarithm of domestic output
$z_t =$	White noise disturbance to the foreign credit component of money supply
$E_{t-j}x_{t+k} =$	The mathematical expectation of variable x at time $t+k$ based on information available at time $t-j$. The $t-j$ information set includes full knowledge of all variables dated $t-j$ or earlier and complete knowledge of the model.

TABLE 2

The Monetary Sector

$$m_t - p_t = \alpha_0 - \alpha_1 i_t + \alpha_2(w_t - p_t); \qquad \alpha_1 > 0,\ 0 \le \alpha_2 \le 1/\theta \tag{1.1}$$

$$i_t = i_t^* + E_t s_{t+1} - s_t \tag{1.2}$$

$$w_t = \gamma + \theta m_t + (1-\theta)(s_t + b_t^*); \qquad 0 < \theta < 1 \tag{1.3}$$

$$m_t = \omega d_t + \delta b_t^g + k \tag{1.4}$$

$$d_t = d_{t-1} + v_t \tag{1.5}$$

$$b_t^g = b_{t-1}^g + z_t \tag{1.6}$$

$$b_t^* = b_t^p - \eta z_t; \qquad \theta\delta = (1-\theta)\eta \tag{1.7}$$

The Goods Market

Flexible Prices:

$$\bar{y} = \beta_0 + \beta_1(p_t - p_t^* - s_t) + \beta_2(w_t - p_t); \qquad \beta_1, \beta_2 \ge 0 \tag{2}$$

Sticky Prices:

$$\bar{y} = \beta_0 - \beta_1(p_t - E_{t-1}[p_t^* + s_t]) + \beta_2(E_{t-1}w_t - p_t) \tag{2.1}$$

Asset Accumulation

$$E_t[(w_{t+1} - p_{t+1}) - (w_t - p_t)] = \psi[(\overline{w - p}) - (w_t - p_t)]; \qquad 0 < \psi < 1 \tag{3}$$

logarithmic linearization of liquid domestic wealth. We take the logarithm of wealth, w_t, to be equal to a constant plus a positively weighted average of the logarithm of money and the logarithm of the domestic nominal value of domestic holdings of traded securities, $s_t + b_t^*$. The weight θ is the share of money in total wealth at the point of linearization. This linearization is appropriate for positive values of the level of domestic net holdings of foreign-denominated securities, which we assume.

Equation (1.4) is a logarithmic approximation of the domestic money stock. It is written as a linear function of the log of domestic credit, d_t, and the log of the central bank's holdings of foreign-currency-denominated traded securities, b_t^g. The weight ω is the ratio of the value of domestic credit to the money stock, and δ is the ratio of the value of foreign bonds held by the central bank to the money supply. Equations (1.5) and (1.6) show that d_t and b_t^g follow a random walk. Equation (1.7) says that an open market operation at the beginning of the period that increases the money supply will reduce private holdings of foreign securities. The restriction that $\theta\delta = (1 - \theta)\eta$ ensures that the value of bonds purchased by the central bank equals the value of the money that is paid for the bonds — so that private wealth is, *ceteris paribus,* unaffected by the operation.

Equation (2) is the condition of equilibrium in the market for domestic output. It states that the constant quantity of domestic output, $\bar{y}$, is equal to the demand for it, $\beta_0 - \beta_1(p_t - p_t^* - s_t) + \beta_2(w_t - p_t)$. In logarithms, the domestic currency price of foreign output is $s_t + p_t^*$, so $p_t - s_t - p_t^*$ is the relative price of domestic goods. Demand also incorporates a wealth effect. We assume that p_t^* is the constant $\bar{p}^*$. The effects of including a real interest rate term in aggregate demand are explored in the Appendix.

When prices are perfectly flexible (2) holds exactly. When prices are sticky we assume that p_t is set such that (2) is expected to hold based on last period's information. p_t, however, is predetermined and cannot adjust to ensure that (2) holds. The price level, with sticky prices, is determined by equation (2.1). Thus, p_t is unresponsive to current surprises, as in the model of Dornbusch (1976). But, unlike the model of Dornbusch, p_t is set each period at the level expected to clear the goods market.

Equation (3) is the condition that the expected rate of change of real wealth, $E_t[(w_{t+1} - p_{t+1}) - (w_t - p_t)]$, equal the desired rate of saving, $\psi[(\overline{w - p}) - (w_t - p_t)]$. We have adopted a target saving function with the target, $\overline{w - p}$, constant. A more complex formulation might allow the target to depend on the level of disposable income and possibly relative goods prices, and the real rate of interest, but we have simplified behavior in this regard.[4]

The next section derives and interprets the model's solution with fully flexible prices.

3. FLEXIBLE PRICES

In this section we solve the flexible price version of the model, with primary attention focused on the exogenous stochastic elements in the model — the monetary shocks v_t and z_t. The sticky price and flexible price versions of our model are very similar. Because in past periods the goods market was expected to clear in the current period, and in the current period the expectation is that the goods market will clear

[4]Goods demand might also depend on the real rate of interest. The flexible price version of our model can easily accommodate real interest rate effects in both saving and goods demand (see Appendix). Solutions of the sticky price model, however, become much more complex with real interest rates present. Results for the sticky price model with real rates of interest are available from the authors on request.

in future periods, the expectations of the current solutions for both versions are identical based on past information, and the current information expectations of the two versions are identical for all periods beyond the current period. We make use of this similarity in obtaining our solutions by first solving the model for flexible prices and then using the flexible price solutions to help in obtaining the sticky price solutions. The sticky price solutions are presented in section 4.

A. Solution to the Model

When prices are freely flexible the model has three key currently determined endogenous variables s_t, p_t, and b^p_{t+1}, one predetermined variable b^p_t, and two exogenous variables $d_t = d_{t-1} + v_t$ and $b^g_t = b^g_{t-1} + z_t$. The stable solution of the model is

$$s_t = \pi_{10} + \pi_{11} d_{t-1} + \pi_{12} v_t + \pi_{13} b^g_{t-1} + \pi_{14} z_t + \pi_{15} b^p_t \tag{4.1}$$

$$p_t = \pi_{20} + \pi_{21} d_{t-1} + \pi_{22} v_t + \pi_{23} b^g_{t-1} + \pi_{24} z_t + \pi_{25} b^p_t \tag{4.2}$$

$$b^p_{t+1} = \pi_{30} + \pi_{31} d_{t-1} + \pi_{32} v_t + \pi_{33} b^g_{t-1} + \pi_{34} z_t + \pi_{35} b^p_t , \tag{4.3}$$

where the values of the coefficients are given in Table 3.

An increase in domestic credit, which increases the money supply by direct transfers to domestic residents, is fully neutral in this model. The coefficient on d_{t-1} and v_t are identical, so only $d_{t-1} + v_t = d_t$ matters with flexible prices. A 1 percent increase in domestic credit leads to an ω percent increase in the money supply. Since $\pi_{11} = \pi_{12} = \pi_{21} = \pi_{22} = \omega$ and $\pi_{31} = \pi_{32} = 0$, domestic credit expansion is neutral.[5]

An open market operation is not neutral. A 1 percent increase in the monetary authority's holdings of foreign bonds increases the money stock by δ percent. Yet π_{14} and π_{24} are greater than δ, and π_{34} is nonzero. The open market operation introduces nonneutralities by temporarily changing domestic wealth. The exchange rate dynamics will be discussed in more detail below. The 1 percent increase in b^g_t through the open market operation leads to an η percent drop in private holdings of

[5]We have adopted a random walk for the money supply, but other processes, where a current disturbance signals to agents a change in the money growth rate will not be neutral. Thus, if the *growth rate* of domestic credit follows a random walk, the percentage change in the exchange rate for a 1 percent change in the growth rate is

$$\omega + \frac{\alpha_1 \omega (\beta_1 + \beta_2)(1 + \alpha_1 \psi)}{\Delta},$$

and the percentage change in prices is

$$\omega + \frac{\alpha_1 \omega (\beta_1 + \beta_2 (1 - \theta))(1 + \alpha_1 \psi)}{\Delta}.$$

These results are consistent with the findings of Flood (1979). However, these results must be interpreted with some caution because the linearization in equation (1.4) may not be appropriate when domestic credit grows more rapidly than foreign credit.

TABLE 3

VALUE OF COEFFICIENTS IN EQUATIONS (4.1)–(4.3)

i/j	π_{ij} 0	1	2	3
1	*	ω	ω	δ
2	*	ω	ω	δ
3	*	0	0	0

i/j	π_{ij} (continued) 4	5
1	$\dfrac{\delta(\beta_1 + \beta_2)(1 + \alpha_1\psi)}{\Delta} > 0$	$-\dfrac{(1 - \theta)(\beta_2 + \beta_1\alpha_2)}{\Delta} < 0$
2	$\dfrac{\delta(\beta_1 + \beta_2(1 - \theta))(1 + \alpha_1\psi)}{\Delta} > 0$	$-\dfrac{(1 - \theta)(\beta_1\alpha_2 - \beta_2\alpha_1\psi)}{\Delta}$
3	$-(1 - \psi)\eta$	$1 - \psi$

NOTES: $\Delta = \beta_1(1 + \alpha_1\psi - \alpha_2\theta) + \beta_2(1 + \alpha_1\psi - \theta) > 0$.
Constants are not reported.

foreign bonds. The coefficient π_{34} tells us residents will try to recoup the fraction ψ of the loss in foreign-denominated bonds over the next period. (Notice, while the open market operation is nonneutral, an increase in b^g_{t-1}, *ceteris paribus,* is neutral: $\pi_{13} = \pi_{23} = \delta$ and $\pi_{33} = 0$.)

π_{15} is negative, so that an increase in b^p_t will lower s_t leading to a more valuable domestic currency. π_{15} shows the relationship between the current account and the exchange rate. With a freely floating exchange rate a current account surplus will be balanced by a capital account deficit. A capital account deficit takes place when domestic residents on net purchase securities from abroad, increasing b^p_t. So, we find a current account surplus contributes to a currency appreciation. We are able to sign π_{15} because positive wealth effects in the money and goods market work in the same direction to appreciate the currency.

π_{25} is ambiguous in sign. In the money market, higher b^p_t creates excess money demand, which would require a price reduction. But, in the goods market higher b^p_t creates excess goods demand, which would require a price increase. As is evident from the coefficient in Table 3, if the wealth effect in money demand is dominant, $\pi_{25} < 0$, and if the wealth effect in goods demand is dominant, $\pi_{25} > 0$.

The value of π_{35} (and π_{34}) that we choose is one of two possible values that fulfill the constraint of rational expectations. Since $0 < \psi < 1$, $(1 - \psi)$ is the only stable value of π_{35}. If b^p_t jumps up one period, residents will divest the fraction ψ of the excess over the next period.

B. *Exchange Rate Dynamics*

We have seen that an open market operation that increases the money supply will initially cause the exchange rate to depreciate more than proportionately. Kouri's (1976) model is in many respects similar to our flexible price model, and he also concluded there would be short-run overshooting.

To understand our overshooting result, first we will make some simplifying assumptions, then see the effects of relaxing those assumptions. So, as in Kouri, first assume purchasing power parity (PPP), so $\beta_1 \to \infty$. Now, following Kouri, initially look at the case of static expectations (which is equivalent to setting $\alpha_1 = 0$). The money demand equation can be rewritten in a reduced form so that real "money demand" depends only on real bond holdings:

$$m_t - p_t = \xi(s_t + b_t^* - p_t); \qquad \xi = \frac{\alpha_2(1 - \theta)}{1 - \alpha_2\theta}.$$

The open market operation raises the nominal money supply and lowers the nominal holdings of foreign bonds. *Ceteris paribus,* this raises the real money supply and lowers the reduced form "money demand." Since the real exchange rate cannot change under PPP, all the adjustment to equilibrate the money market must happen on the real money supply side. The price level must rise even more than the nominal money stock to cause a fall in the real money supply. From PPP, it follows the exchange rate also rises more than proportionately. This is the essence of Kouri's overshooting result. If PPP does not hold, so β_1 is finite, then the fall in real wealth leads to a decrease in aggregate demand that must be offset by a real depreciation. The exchange rate must rise even more than the price level.

Now suppose expectations of a depreciation do affect money demand, so $\alpha_1 > 0$. Let us first consider the case where $\psi = 1$, so that the public fully restores its wealth to the target level in just one period. Then, by period $t + 1$ the public will bring its holdings of foreign bonds back to their previous level, and there will be no expected real effects from the open market operation persisting into period $t + 1$. The exchange rate and the price level in period $t + 1$ are expected to have increased by the same percentage as the original increase in the money stock. Since the exchange rate initially depreciated more than proportionally in period t, there is an expectation of an appreciation between periods t and $t + 1$. This tends to raise real money demand, thus dampening overshooting. For smaller $\psi(\psi < 1)$, the expectation of appreciation is smaller (since the holdings of real wealth do not adjust fully to the long run in one period) and the overshooting as a consequence is larger.

C. *Sterilized Intervention*

Sterilized intervention consists of open market operations that purchase or sell foreign securities but are accompanied by changes in domestic credit so as to leave the overall money stock unchanged. In our model, for example, a sale of foreign-currency-denominated bonds to domestic residents along with an expansion of domestic credit to restore the nominal money supply to its initial level would represent sterilized intervention in support of the domestic currency. The percentage change in any variable x_t in response to a 1 percent change in domestic residents' holdings of foreign bonds as a result of sterilized intervention is given by $1/\eta[(\delta/\omega)(dx_t/dv_t) - (dx_t/dz_t)]$, where dx_t/dv_t and dx_t/dz_t represent the percentage change in x_t for a 1 percent change in the central bank's holdings of domestic and foreign credit, respectively.

In this version of the model the effects of sterilized intervention are exactly the same as the effects of a change in the predetermined level of holdings of foreign-denominated securities by the public, b_t^p, because all prices are fully flexible. Thus sterilized intervention has a short-run impact on exchange rates because it changes the wealth of the public. Intervention in support of the currency will increase domestic residents' wealth, which works to appreciate the currency both through its effect in increasing aggregate demand and its effect in increasing money demand.

Sterilized intervention has an effect here because the private sector does not include in their wealth a "correction" involving the present discounted value of future tax liabilities. If such a correction were present, their wealth would be invariant to a shift in foreign bonds from private to public ownership or vice versa. Such a situation would be one of Ricardian equivalence. It is well known, though, that Ricardian equivalence breaks down in a number of plausible circumstances; for example, if individuals' horizons are finite while the governments' is not.

4. STICKY PRICES

This section examines the model when goods prices are set at the level expected to clear the goods market this period where expectations are based on last period's information.

A. *Solution to the Model*

For the sticky prices, the currently determined variables are s_t and b_{t+1}^p, with p_t and b_t^p predetermined and $d_t = d_{t-1} + v_t$ and $b_t^g = b_{t-1}^g + z_t$ exogenous. To obtain a solution we replace (2) in the flexible price model with (2.1), and we recall that the values $E_{t-1}x_t$, $x_t = s_t$, p_t, b_t^p are identical for flexible and for sticky prices. Consequently, the sticky price solutions will differ from the flexible price solutions only in the values of the coefficients attached to v_t and z_t. For the sticky price solutions let λ_{12}, λ_{22}, and λ_{32} be the coefficients attached to v_t and λ_{14}, λ_{24}, and λ_{34} be the coefficients attached to z_t in the s_t, p_t, and b_{t+1}^p equations, respectively. The coefficients are reported in Table 4.[6]

Prices are predetermined, so they do not respond to monetary shocks in the current period. Hence, $\lambda_{22} = \lambda_{24} = 0$.

Unanticipated monetary shocks have a quite different impact on future foreign bond holdings, b_{t+1}^p, under sticky prices as compared to flexible prices. An increase in domestic credit has no impact on b_{t+1}^p under flexible prices, but since λ_{32} is

[6]The percentage change in the exchange rate for a 1 percent change in the money growth rate is

$$\frac{\omega[\beta_1(1 + \alpha_1)[(1 + \alpha_1)(1 + \alpha_1\psi) - \alpha_2\theta] - \beta_2\theta\alpha_1(1 - \psi)]}{\Delta^*}.$$

However, see note 5 for a cautionary note.

TABLE 4

VALUES OF COEFFICIENTS ON MONEY SURPRISES (v_t AND z_t) IN STICKY PRICE MODEL

i/j	λ_{ij}: 2	λ_{ij}: 4
1	$\dfrac{\omega[\beta_1(1+\alpha_1)(1-\alpha_2\theta+\alpha_1\psi)-\beta_2(1-\psi)\alpha_1\theta]}{\Delta^*}$	$\dfrac{\delta(1+\alpha_1)(1+\alpha_1\psi)\beta_1}{\Delta^*} > 0$
2	0	0
3	$\dfrac{\omega(1-\psi)(1-\theta+\alpha_1)\Delta}{(1-\theta)\Delta^*} > 0$	$\dfrac{\delta(1+\alpha_1)(1-\psi)\Delta}{\Delta^*} > 0$

NOTES: $\Delta = \beta_1(1+\alpha_1\psi-\alpha_2\theta)+\beta_2(1-\theta+\alpha_1\psi) > 0$.
$\Delta^* = \beta_1[\alpha_1(1+\alpha_1\psi)+\alpha_2(1+\alpha_1)(1-\theta)]+\beta_2\alpha_1(1-\psi)(1-\theta) > 0$.

positive, a positive shock to domestic credit raises b^p_{t+1} with sticky prices. While under flexible prices an open market purchase of foreign bonds led to a lower b^p_{t+1}, under sticky prices, since $\lambda_{34} > 0$, future bond holdings actually increase. That is, domestic residents will more than recoup in period $t+1$ the bonds that were purchased from them to period t.

The open market purchase has no direct effect on private wealth but λ_{14} shows that the operation will cause the domestic currency to depreciate. With sticky prices this implies a real depreciation, and thus an increase in real wealth of private citizens from a rise in the real value of their foreign bond holdings. Eventually private citizens hope to dissave until their real wealth is restored to its initial level, $\overline{w-p}$, but they intend to adjust only part of the way in the next period. Thus, if they were initially holding $\overline{w-p}$, they intend in period $t+1$ to be holding $\overline{w-p} + \phi(\overline{w-p}-(w_t-p_t))$. However, in period $t+1$ the price level is expected to rise rapidly, and under usual circumstances the exchange rate is also expected to appreciate. Indeed, in period $t+1$ the real exchange rate is expected to have *appreciated* beyond its long-run level (as it must, from equations (2), if $w_{t+1}-p_{t+1}$ is above its long-run level). This rapid appreciation of the real exchange rate, and rapid rise in the price level will tend to quickly diminish the real value of foreign bonds and money, respectively. Private citizens do not want to see their wealth diminish so rapidly—they prefer a gradual adjustment. To forestall this loss of wealth they will accumulate foreign bonds to help offset their capital losses. In fact, they will more than fully replace the bonds that were purchased from them in the open market operation. If they were just to replace the bonds, given the real appreciation, the real value of the bond holdings would lie below their long-run value (as would the real value of their money holdings, as can be seen from a reduced-form money demand equation).[7] Thus, to maintain their wealth at a level above $\overline{w-p}$ in period

[7]A reduced-form money demand equation for period $t+1$ is

$$m_{t+1}-p_{t+1} = -\xi_1 E_{t+1}(s_{t+2}-s_{t+1}) + \xi_2(s_{t+1}+b^*_{t+1}-p_{t+1}).$$

The text argues that $s_{t+1}-p_{t+1}$ lies below its long-run value, so if b^*_{t+1} were to be merely at its long-run value, real bond holdings would lie below their long-run value. Furthermore, if $w_{t+1}-p_{t+1}$ is above its long-run value, $E_{t+1}(s_{t+2}-s_{t+1})$ must be positive. Both effects tend to push $m_{t+1}-p_{t+1}$ below its long-run value. But this tells us both real money and real bonds would lie below their long-run value, which contradicts the fact that $w_{t+1}-p_{t+1}$ is above its long-run value. Hence, b^*_{t+1} must be greater than its long-run level.

$t + 1$ a rather large accumulation of foreign bonds is required, which in turn calls for a large current account surplus.

The analysis of why an expansion in domestic credit has a positive impact on future foreign bond holdings is much the same as for the open market operation. The chief difference is in the cause for the initial increase in wealth. Nominal wealth is increased directly by the expansion of domestic credit. There is also an indirect effect coming from the change in the value of the currency, but ambiguity in the sign of λ_{12} makes this effect ambiguous. The direct effect of the monetary expansion, however, is always dominant, so real wealth will increase initially.

These results concerning λ_{32} and λ_{34} may be model specific. If prices were to adjust more slowly than we have assumed then inflation would cause a smaller real capital loss between t and $t + 1$ and accumulation of foreign-denominated securities may not be required. On the other hand, consideration of a Keynesian saving function that depends on current real income would tend to reinforce our results. The initial depreciation would lead to an expansion in aggregate demand, and thus real GNP. This would raise the level of saving, which would require a greater acquisition of foreign bonds.

B. Exchange Rate Dynamics

As in the flexible price model, to understand the response of the exchange rate to an open market purchase of foreign-denominated bonds, it is useful initially to make some simplifying assumptions. Let us consider first the case where there are no real wealth effects in money demand, so $\alpha_2 = 0$. Then, the situation is much like that in Dornbusch (1976). The increase in the money supply from the open market operation requires an expectation of an appreciation for the money market to clear. Consider the case where $\psi = 1$. By period $t + 1$, there are expected to be no real effects from the open market operation. Prices and real wealth will have adjusted completely. Thus, the exchange rate and price level in period $t + 1$ are expected to have increased by the same percentage as the original increase in the money stock. In order to generate the required expectation of an appreciation, initially the exchange rate must increase by a greater percentage than did the money stock. This is the essence of Dornbusch's overshooting result.

Notice that the depreciation causes real wealth to increase. If real wealth levels are not expected to be restored fully to their target level by period $t + 1$ (because $\psi < 1$), then the exchange rate must be expected to be lower than its long-run value in period $t + 1$, in order to clear the goods market in that period. This leads to a tendency for the expected next period's spot rate to be less than its long-run value.[8] Hence, the current depreciation required to generate the expected appreciation necessary to clear the money market this period is smaller. This is one

[8]Under the assumption $\alpha_2 = 0$, $E_t s_{t+1}$ must be lower than its long-run value. If $E_t s_{t+1}$ were greater than its long-run value, there would be an expectation of depreciation between periods $t + 1$ and $t + 2$. For the money market to clear in period $t + 1$, then, $E_t p_{t+1}$ would need to be below its long-run value. But $E_t s_{t+1}$ above its long-run value, and $E_t p_{t+1}$ below contradicts the requirement that there be an expected real appreciation (relative to the long run) in period $t + 1$.

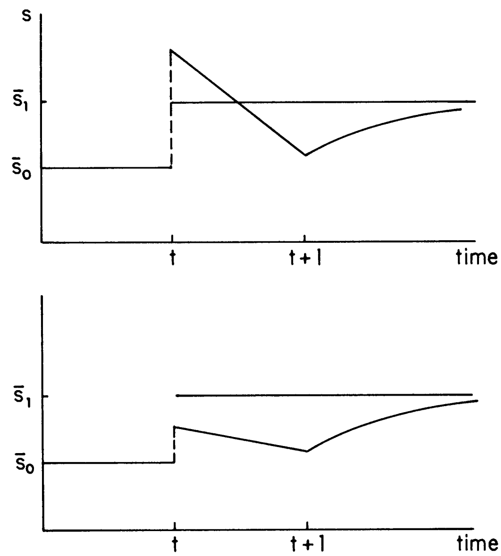

FIG. 1. Exchange Rate Dynamics

factor that leads to a dampening of Dornbusch overshooting when wealth effects are considered.

A more direct influence of wealth in diminishing overshooting comes through the effects of change in real wealth on money demand ($\alpha_2 > 0$). The open market operation itself has no effects on holdings of real wealth, but the ensuing depreciation raises real wealth. This has an independent effect of raising money demand, so that the required expectation of appreciation can be smaller. Hence, the current exchange rate does not need to depreciate so much and may not even overshoot. Two possible paths of the exchange rate are depicted in Figure 1.[9]

A bit more formally, in our model with no wealth effects we get a version of the Dornbusch overshooting result:

$$\lim_{\alpha_2, \beta_2 \to 0} \lambda_{14} = (1 + \alpha_1)/\alpha_1 > 1 .$$

But, in general, $\lambda_{14} < (1 + \alpha_1)/\alpha_1$, so wealth effects dampen the overshooting.

It is useful to contrast the direct effects of real wealth changes in the flexible and sticky price versions of the model. An open market purchase of foreign securities initially lowers real wealth under *flexible* prices. This leads to a drop in money demand, which tends to magnify the effect of the money supply increase. On the

[9]There is a third possibility, not pictured. If the wealth elasticity of money demand, α_2, is sufficiently large, there may be an expected depreciation between t and $t + 1$. Thus, following the open market operation the exchange rate is expected to depreciate monotonically to its long-run value. The circumstances under which this will happen, however, seem unlikely. For example, given the restriction $\alpha_2\theta < 1$, a sufficient condition for this not to occur is $\theta > 1 - \theta$—that is, real money holdings exceed real holdings of foreign bonds. Another sufficient condition is simply $\alpha_2 < 1$.

other hand, under *sticky* prices, the same open market operation temporarily raises real wealth. This raises money demand, which works to moderate the effects of the jump in the money supply.

The dynamics of the exchange rate in the presence of wealth effects are quite interesting. Initially the money supply increase leads to a real depreciation and possibly overshooting. But, real wealth of domestic residents also increases. Over a somewhat larger horizon, this increased real wealth *raises* the real value of the domestic currency and causes the nominal exchange rate to lie below its long-run value. The increase in real wealth raises real money demand and aggregate demand, with both effects tending to increase the value of the currency. Thus the initial effects of the open market operation are reversed. Only in the long run will the currency depreciate to the full extent of the money supply increase and leave real variables unchanged.

Consider the opposite case. Between 1980 and 1982 the dollar appreciated greatly. There was much talk of the dollar being "overvalued"—that is, the exchange rate overshot its long-run value (see Frankel 1983). Subsequently, the United States began to run record current account deficits—as would be predicted by the model. As goods prices adjust, real interest rates should fall back to more normal levels and the value of the dollar should begin to fall back. But, it will not merely depreciate to its new long-run level. It will depreciate beyond that because the gigantic current account deficits have diminished domestic wealth. Thus, while in the short run the dollar may overshoot due to liquidity effects, in a somewhat longer horizon the resulting current account deficits will lead to (a) an undershooting of the exchange rate, and (b) a fall in the real value of the dollar. Only in the very long run will a monetary expansion be neutral in its effects.

The exchange rate response to an increase in domestic credit is much the same as for an open market operation, except in the first period. Wealth effects still dampen the Dornbusch overshooting, but the direct transfer of wealth to the public from the "helicopter drop" of money could actually lead to an appreciation of the currency initially. After this possibly perverse impact response, the dynamics of the exchange rate are identical to those described above following an open market operation.

C. *Sterilized Intervention*

As in the case of flexible prices, sterilized intervention in support of the currency will lead to a temporary appreciation of the domestic currency. Unlike the case of flexible prices, the effect is not the same as an increase in the predetermined b_t^p. But, the unanticipated increase in foreign bond holdings from the intervention directly raises money demand and thus appreciates the currency. The percentage change in the exchange rate for an operation that increases public holdings of foreign-currency-denominated bonds by 1 percent is given by

$$-\frac{(1-\theta)[\beta_1(1+\alpha_1)\alpha_2+\beta_2(1-\psi)\alpha_1]}{\Delta^*}<0,$$

where Δ^* is defined as in Table 4.

5. CONCLUSIONS

The model developed in this paper weaves together two strands in the exchange rate literature — the sticky price models and the models in which the current account plays an important role. Prices are set a period ahead of time at the level that is expected to clear the goods market. So, prices are predetermined and do not respond to current shocks, but in the absence of any further surprises the goods market will clear after one period. The dynamics of movement of the economy toward the steady state depend on the slow adjustment of wealth to a target level.

We have made strong assumptions in this paper, and our results clearly depend upon them. The assumption on the speed of adjustment of prices was critical to our obtaining analytic results. Nonetheless, we think the model may capture aspects of a world in which prices adjust slowly, but not as slowly as real wealth holdings. The results concerning the dampening of Dornbusch overshooting, the nonmonotonic adjustment of the exchange rate following its initial jump, and the effectiveness of sterilized intervention all seem to some degree plausible, and, in any event, are testable.

APPENDIX

Modifications to Include a Real Rate of Interest in the Flexible Price Model

With real rates of interest included, the goods market and the saving equations are

$$\bar{y} = \beta_0 - \beta_1(p_t - p_t^* - s_t) + \beta_2(w_t - p_t) - \beta_3\rho_t \tag{A1}$$

$$E_t[(w_{t+1} - p_{t+1}) - (w_t - p_t)] = \psi_1[(\overline{w - p}) - (w_t - p_t)] + \psi_2\rho_t\,, \tag{A2}$$

where $\rho_t \equiv i_t - E_t(p_{t+1} - p_t) = i_t^* + E_t(s_{t+1} - p_{t+1}) - E_t(s_t - p_t)$. For this appendix we will continue to assume i_t^* and p_t^* to be constants. Equations (A1) and (A2) comprise a second-order difference equation system in $g_t \equiv w_t - p_t$ and $f_t \equiv p_t - s_t$. A semi-reduced form solution of this system will have the form

$$f_t = \lambda_0 + \lambda_1 g_t, \tag{A3}$$

where λ_0 is a constant and

$$\lambda_1 = \frac{1}{2}\left\{-\left(\frac{\beta_1 + \beta_3\psi_1 - \beta_2\psi_2}{\beta_1\psi_2}\right) + \left[\left(\frac{\beta_1 + \beta_3\psi_1 - \beta_2\psi_2}{\beta_1\psi_2}\right)^2 + \frac{4\beta_2}{\beta_1\psi_2}\right]^{1/2}\right\}.$$

Now use (A3) in (A2) to obtain

$$E_t[(w_{t+1} - p_t) - (w_t - p_t)] = \tilde{\psi}_0 + \tilde{\psi}_1[(\overline{w - p}) - (w_t - p_t)], \tag{A4}$$

where $\tilde{\psi}_0$ is a constant and $\tilde{\psi}_1 = \psi_1/(1 + \psi_2\lambda_1)$. Now use (A3) and (A4) in (A1) to obtain

$$\bar{y} = \tilde{\beta}_0 - \beta_1(p_t - p_t^* - s_t) + \tilde{\beta}_2(w_t - p_t), \tag{A5}$$

where $\tilde{\beta}_0$ is a revised constant and $\tilde{\beta}_2 = \beta_2 - \beta_3\lambda_1\tilde{\psi}_1$.

This kind of transformation of the flexible price model is possible because the real (goods market and saving) components of the model and the nominal component are recursive. The real sector can be solved without regard to the monetary sector. This is not true when prices are sticky. Therefore no simple redefinition of parameters will accommodate excluded real rates of interest. Results for our model with a real rate of interest included are available from the authors on request.

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