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REAL EXCHANGE RATE EFFECTS OF MONETARY SHOCKS UNDER FIXED AND FLEXIBLE EXCHANGE RATES

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We analyze how the real exchange rate effects of monetary and real shocks depend on the exchange rate regime within a two-country rational expectations model with confusion about money and real shocks. The model demonstrates that the real exchange rate effect of unanticipated monetary shocks is negatively related to the variance of the domestically-created money supply growth, and that the effects of increasing domestic money variance on the real exchange rate are less under a fixed rate regime than under a flexible rate regime.

1. Introduction

Rational expectations models of monetary policy suggest that the real effects of unanticipated monetary disturbances decrease as the relative variance of monetary shocks increases [see, for example, Lucas (1972, 1975) and Barro (1980)]. Lucas (1973), Kormendi and Meguire (1984), and Fry and Lilien (1986) have found support for this hypothesis in tests of the relation between the variance of monetary shocks and the effects of such shocks on real output across countries.

One problem with such cross-country tests is that they neglect the possible role of differences in exchange rate regimes across countries. Kimbrough (1984), for example, shows that the degree to which an unanticipated money supply change is perceived by agents, and therefore the output effect of a money shock, depend on the exchange rate regime. Under a flexible exchange rate regime, exchange rate movements, in combination with other price

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changes associated with a particular disturbance, help agents infer the nature of disturbances. Under a fixed rate regime, agents essentially lose the foreign exchange market as an information source, unless central banks reveal the extent of their foreign exchange market intervention.

In this paper we analyze theoretically how the real effects of monetary shocks depend on the exchange rate regime. These effects depend on the ability of agents to infer the source of disturbances under different regimes, as well as on the degree to which disturbances within different countries are contained or diffused by exchange rate adjustment. We are particularly interested in deriving propositions concerning the relationship between the variances of domestic and foreign unanticipated money shocks and the real exchange rate effects of monetary policy under both flexible and fixed exchange rates. Our emphasis on real exchange rate effects, rather than on output effects, stems from several factors. First, the behavior of the real exchange rate under flexible exchange rates is a major policy concern due to its impact on output as well as on trade flows. Secondly, for future empirical work it may be advantageous to analyze monetary influences on a real price variable such as the real exchange rate, instead of output, since the latter effects may be more intractable due to adjustment lags. Moreover, in our framework, results regarding real exchange rate effects can be translated directly into output effects.

We formulate a two-country rational expectations model of real exchange rate determination based on the assumption that economic agents possess imperfect information about money supply growth and real demand and supply conditions. Within this model we illustrate how the degree of confusion and the magnitude of the real exchange rate effects of disturbances depend on the exchange rate regime. We abstract from other possible causes of real exchange rate adjustment to monetary disturbances such as slow price adjustment.[1]

The assumption of imperfect information has also been employed in international macroeconomics models by Bhandari (1982), Kimbrough (1983, 1984), Koh (1984), Flood and Hodrick (1985a, 1985b), Glick and Wihlborg (1986), and Glick (1986). Except for the work of Kimbrough, however, these models generally analyze the nature of adjustment under flexible exchange rates only. Our model addresses the fixed exchange rate case as well. In contrast to Kimbrough, our two-country framework enables analysis of the role of foreign as well as domestic disturbances.

The organization of the paper is as follows. In section 2 we develop a two-country model of goods market equilibrium in which the real exchange rate and the real interest rate are shown to depend on real demand and cost disturbances and on expectations about the future real exchange rate. In

[1]See, for example, Dornbusch (1976), Obstfeld (1985), and Wihlborg and Antoncic (1986).

section 3 we model money markets in the two countries under flexible exchange rates and show how both monetary and real disturbances may influence the real exchange rate. Agents' perceptions of each period's shock depend on 'signals' obtained by observing current goods and asset market prices and conditions. The nature of the signals provided by money markets depends importantly on the exchange rate regime. In section 4 we discuss the distinction between fixed and flexible exchange rates and model the money markets under fixed exchange rates. We compare the magnitude of adjustment of the real exchange rate to different disturbances with that under the flexible rate regime. In this section we also ask whether Kimbrough's (1984) result that a fixed exchange rate regime is informationally inferior to a flexible regime can be extended to a two-country model. Propositions are derived concerning the real exchange rate effects of monetary disturbances in both countries and for differences in adjustment across exchange rate regimes. Section 5 discusses extensions to the basic model. In section 6 we present conclusions.

2. Real exchange rate determination in goods markets

This section formulates a two-country model of the adjustment of the real exchange rate and real interest rates to demand and cost disturbances in the two countries. In the notation below all lower case variables other than interest rates are natural logarithms.

The two economies produce distinct outputs. Aggregate output supply in the domestic country y_t^s depends positively on the domestic real interest rate r_t and negatively on an unobservable random cost disturbance c_t.[2] A similar relationship (in which the foreign counterparts of domestic symbols are marked by asterisks) governs the aggregate supply of foreign output:

$$y_t^s = a_0 + a_1 r_t - c_t, \qquad y_t^{*s} = a_0^* + a_1^* r_t^* - c_t^*, \tag{1}$$

$$c_t = \rho_c c_{t-1} + \varepsilon_{ct}, \qquad c_t^* = \rho_c^* c_{t-1}^* + \varepsilon_{ct}^*. \tag{2}$$

The specification of supply in (1) as a function of the real interest rate reflects the intertemporal decision of producers concerning how much of their product to supply in the current period and how much to supply in the future.[3] The domestic (foreign) cost disturbance consists of a serially-

[2] It is implicitly assumed that agents know the distribution functions of all random variables as well as the structural parameters of the economies of the two countries, but cannot observe aggregate quantities, such as output. Thus, individual observations of quantity variables are idiosyncratic and completely uninformative about aggregate cost and other disturbances introduced below.

[3] Work employing this specification includes Barro (1980), Bhandari (1982), Kimbrough (1984), and Glick (1986).

correlated term and a current (white-noise) shock term, ε_{ct} (ε^*_{ct}). This disturbance can be associated with exogenous factor cost increases or adverse productivity movements.

Aggregate demand for the domestic (foreign) country's output depends negatively on the domestic (foreign) real interest rate, negatively (positively) on the real exchange rate q_t, defined as the price of domestic output in terms of foreign goods, and positively on a random disturbance term d_t (d^*_t):

$$y^{\mathrm{d}}_t = b_0 - b_1 r_t - b_2 q_t + d_t, \qquad y^{*\mathrm{d}}_t = b^*_0 - b^*_1 r^*_t + b^*_2 q_t + d^*_t, \tag{3}$$

$$d_t = \rho_d d_{t-1} + \varepsilon_{dt}, \qquad d^*_t = \rho^*_d d^*_{t-1} + \varepsilon^*_{dt}. \tag{4}$$

The domestic (foreign) demand disturbance term is unobservable and serially correlated with a white-noise shock term ε_{dt} (ε^*_{dt}). It may be interpreted as representing the effect on demand for locally-produced output of autonomous private or fiscal spending arising either domestically or abroad. For simplicity, we have ignored direct income interactions between the demands for output in the two regions. We relax this assumption in section 5.

Let s_t denote the nominal exchange rate, defined as the foreign curency price of domestic currency, and let p_t (p^*_t) denote the domestic-money (foreign-money) price of domestic (foreign) output. Then the real exchange rate q_t is defined as:

$$q_t = s_t + p_t - p^*_t. \tag{5}$$

Denoting the home and foreign nominal interest by i_t and i^*_t, respectively, real interest rates are:

$$r_t = i_t - (\mathrm{E}_t p_{t+1} - p_t), \qquad r^*_t = i^*_t - (\mathrm{E}_t p^*_{t+1} - p^*_t), \tag{6}$$

where E_t denotes expectations formed at time t.[4]

Assuming risk neutrality and perfect capital mobility, equilibrium in the international bond market requires that the domestic nominal interest rate i_t equals the foreign nominal interest rate i^*_t minus the expected nominal appreciation of the domestic currency (which may be zero under a fixed exchange rate regime):

$$i_t = i^*_t - (\mathrm{E}_t s_{t+1} - s_t). \tag{7}$$

[4]Defining the real interest rate in terms of the price of locally-produced output as opposed to a weighted average of domestic and foreign output prices does not affect results. The same assumption is maintained below in the definition of the real balance deflator in the money market.

A direct consequence of this nominal interest parity condition and the definitions of the real interest rates and the real exchange rate is the following real interest parity condition:

$$r_t = r_t^* - (\mathrm{E}_t q_{t+1} - q_t). \tag{8}$$

The goods market equilibrium conditions in the two countries may be used to derive semi-reduced-form equilibrium expressions for the real exchange rate and the domestic real interest rate by setting $y_t^{\mathrm{d}} = y_t^{\mathrm{s}}$ and $y_t^{*\mathrm{d}} = y_t^{*\mathrm{s}}$, substituting for r_t^*, d_t, d_t^*, c_t, and c_t^* with (8), (4), and (2), respectively, and solving jointly for q_t and r_t:

$$\begin{aligned} q_t = {} & H_0 + H_1 E_t q_{t+1} - H_2(\rho_d^* d_{t-1}^* + \varepsilon_{dt}^* + \rho_c^* c_{t-1}^* + \varepsilon_{ct}^*) \\ & + H_3(\rho_d d_{t-1} + \varepsilon_{dt} + \rho_c c_{t-1} + \varepsilon_{ct}), \end{aligned} \tag{9}$$

$$\begin{aligned} r_t = {} & K_0 - K_1 E_t q_{t+1} + K_2(\rho_d^* d_{t-1}^* + \varepsilon_{dt}^* + \rho_c^* c_{t-1}^* + \varepsilon_{ct}^*) \\ & + K_3(\rho_d d_{t-1} + \varepsilon_{dt} + \rho_c c_{t-1} + \varepsilon_{ct}), \end{aligned} \tag{10}$$

where

$$K_0 = \frac{(b_0 - a_0)(a_1^* + b_1^* + b_2^*) + (b_0^* - a_0^*) b_2}{H_4},$$

$$K_1 = \frac{b_2(a_1^* + b_1^*)}{H_4}, \qquad K_2 = \frac{b_2}{H_4}, \qquad K_3 = \frac{(a_1^* + b_1^* + b_2^*)}{H_4},$$

$$H_0 = \frac{(b_0 - a_0)(a_1^* + b_1^*) - (b_0^* - a_0^*)(a_1 + b_1)}{H_4},$$

$$H_1 = \frac{(a_1 + b_1)(a_1^* + b_1^*)}{H_4}, \qquad H_2 = \frac{(a_1 + b_1)}{H_4}, \qquad H_3 = \frac{(a_1^* + b_1^*)}{H_4},$$

$$H_4 = (a_1 + b_1)(a_1^* + b_1^* + b_2^*) + b_2(a_1^* + b_1^*).$$

Assuming $b_0 > a_0$ and $b_0^* > a_0^*$, all coefficients (except possibly H_0) are positive and depend on the a and b parameters of the demand and supply expressions.

Expression (9) states that the current real exchange rate depends positively (negatively) on current and lagged domestic (foreign) demand and cost shocks, and positively on the expected future real exchange rate. Intuitively, an increase in domestic demand or supply costs creates excess demand pressure in the domestic goods market. This induces a relative price shift in favor of domestic goods, i.e. a real appreciation of the domestic currency. An expected real appreciation, i.e. an expected increase in the future relative price of domestic goods, implies a lower domestic real interest rate. This creates excess demand pressure by inducing lower current supply and higher current demand for domestic output. Consequently, a real current domestic currency appreciation is necessary to reduce current demand. Note also that the domestic real interest rate depends positively on both domestic and foreign real disturbances. As has been noted by others [e.g. Obstfeld (1985)], flexible exchange rates do not insulate a country's real interest rate (and correspondingly, its output level) from foreign shocks.

Observe from (9) and (10) that q_t, r_t, and, because disturbances are serially correlated, $E_t q_{t+1}$ as well, depend on domestic and foreign additive composites of the unobservable current disturbances, $d_t + c_t$ and $d_t^* + c_t^*$. Assuming that (i) at any time t agents can observe the current market prices r_t and q_t, (ii) they know the magnitudes of all lagged disturbances, d_{t-1}, c_{t-1}, d_{t-1}^*, and c_{t-1}^*, and (iii) they form expectations identically from homogeneous information sets, observation of the goods markets equilibrium conditions provides agents with two excess demand signals, $S_{gt} = \varepsilon_{dt} + \varepsilon_{ct}$ and $S_{gt}^* = \varepsilon_{dt}^* + \varepsilon_{ct}^*$, which are composites of the underlying current shock components of the disturbances.[5] As long as the serial correlation coefficients for demand and cost disturbances are unequal ($\rho_d \neq \rho_c, \rho_d^* \neq \rho_c^*$), agents have an incentive to distinguish among current demand and cost shocks in order to better infer the serially correlated component of future disturbances.

We conclude this section by noting that the effects of disturbances on the real exchange rate can be translated directly into output effects. The aggregate supply equation (1) implies that output depends on real interest rate and actual (local) cost conditions. From (10), the real interest rate in turn depends on the actual realizations of real disturbances and the expected real exchange rate. Thus the real output as well as real exchange rate effects of confusion about disturbances is transmitted through the impact of this confusion on the expected real exchange rate. We show in the next two sections how money markets, first under flexible exchange rates and subsequently under fixed exchange rates, provide additional signals about current real disturbances to the real exchange rate.

3. Money markets and equilibrium under flexible exchange rates

We assume that in each country money demand depends positively on local output and the local price level and negatively on the local nominal

[5]Note that even if the real price variables q and r are not directly observable, q can be discerned from the observation of the nominal variables, s, p, and p^*; while r can be determined from i through (6) with knowledge of price expectations which are identical for all agents.

interest rate. Under flexible exchange rates, money market equilibrium requires that the locally-created money supply in each country, m_t and m_t^*, equals money demand:

$$m_t = p_t + \alpha_2 y_t - \alpha_1 i_t, \qquad m_t^* = p_t^* + \alpha_2^* y_t^* - \alpha_1^* i_t^*. \tag{11}$$

m_t (m_t^*) is assumed unobservable and determined exogenously as the sum of a serially-correlated term and a white-noise term:

$$m_t = \rho_m m_{t-1} + \varepsilon_{mt}, \qquad m_t^* = \rho_m^* m_{t-1}^* + \varepsilon_{mt}^*. \tag{12}$$

Recall that the nominal price variables p, s, and p^* are definitionally linked by the real exchange rate q according to eq. (5). The money market equilibrium conditions in the two countries can be used to solve for any two among these three variables. Solving for p and s, the domestic money market equilibrium condition, together with (3), (4), and (6), can be used to derive the following expression for the domestic price level:[6]

$$\begin{aligned} p_t(1+\alpha_1) = {} & \rho_m m_{t-1} + \varepsilon_{mt} - \alpha_2 b_0 + (\alpha_2 b_1 + \alpha_1) r_t + b_2 \alpha_2 q_t \\ & + \alpha_1 \mathrm{E}_t p_{t+1} - \alpha_2(\rho_{t+1} d_{t-1} + \varepsilon_{dt}), \end{aligned} \tag{13}$$

while the foreign money market condition, together with (3)–(8), provides the following expression for the nominal exchange rate:

$$\begin{aligned} s_t(1+\alpha_1^*) = {} & \rho_m^* m_{t-1}^* + \varepsilon_{mt}^* - (1+\alpha_1^*) p_t - \alpha_2^* b_0^* + (\alpha_2^* b_1^* + \alpha_1^*) r_t \\ & + (1 - \alpha_2^*(b_2^* + b_1^*)) q_t + \alpha_2^* b_1^* \mathrm{E}_t q_{t+1} + \alpha_1^* \mathrm{E}_t p_{t+1} \\ & + \alpha_1^* \mathrm{E}_t s_{t+1} - \alpha_2^*(\rho_d^* d_{t-1}^* + \varepsilon_{dt}^*). \end{aligned} \tag{14}$$

The above two expressions yield the money market signals $S_{mt} = \varepsilon_{mt} - \alpha_2 \varepsilon_{dt}$ and $S_{mt}^* = \varepsilon_{mt}^* - \alpha_2^* \varepsilon_{dt}^*$, respectively, which are composites of local real demand and money supply shocks.

To determine the equilibrium adjustment of the real exchange rate, recall that q depends on current real disturbances and on expectations of the future value of q from (9) and that the serially correlated nature of disturbances implies that these expectations depend on current disturbances as well.

[6]Note that (3) is used to substitute for y_t and y_t^*. This implicitly assumes that money demand depends on goods demand and leads to the result below that the money market signals depend on real demand disturbances. Using (1) instead would cause these signals to depend on real cost disturbances. The final results are independent of which assumption is made.

Accordingly, we postulate the following reduced-form equilibrium relation between the real exchange rate and current and lagged disturbances:

$$q_t = \bar{q} + B_m m_{t-1} + B_d d_{t-1} + B_c c_{t-1} + B_m^* m_{t-1}^* + B_d^* d_{t-1}^* + B_c^* c_{t-1}^*$$
$$+ B_m^\varepsilon \varepsilon_{mt} + B_d^\varepsilon \varepsilon_{dt} + B_c^\varepsilon \varepsilon_{ct} + B_m^{\varepsilon *} \varepsilon_{mt}^* + + B_d^{\varepsilon *} \varepsilon_{dt}^* + B_c^{\varepsilon *} \varepsilon_{ct}^*, \tag{15}$$

where $\bar{q}$ is the long-run average real exchange rate and the B coefficients, indicating the sensitivity of q to current and lagged disturbances, depend on the structural parameters of the system in a manner described below. (It is shown below that the lagged money coefficients, B_m and B_m^*, are both zero.) Solutions for the other endogenous variables – r, p, and s – can be postulated in an analogous manner. $E_t q_{t+1}$ in (9) is obtained by forming expectations of the forward-dated equivalent of (15).

Agents' expectations of the shocks in period t are conditional on the information set containing the four signals S_g, S_g^*, S_m, and S_m^*. These expectations can be computed from projections on the signals:[7]

$$\begin{bmatrix} E_t\varepsilon_{mt} \\ E_t\varepsilon_{dt} \\ E_t\varepsilon_{ct} \\ E_t\varepsilon_{mt}^* \\ E_t\varepsilon_{dt}^* \\ E_t\varepsilon_{ct}^* \end{bmatrix} = \begin{bmatrix} 0 & \sigma_m^2 & 0 & 0 \\ \sigma_d^2 & -\alpha_2\sigma_d^2 & 0 & 0 \\ \sigma_c^2 & 0 & 0 & 0 \\ 0 & 0 & 0 & \sigma_m^{*2} \\ 0 & 0 & \sigma_d^{*2} & -\alpha_2^*\sigma_d^{*2} \\ 0 & 0 & \sigma_c^{*2} & 0 \end{bmatrix}$$

$$\times \begin{bmatrix} \sigma_d^2+\sigma_c^2 & -\alpha_2\sigma_d^2 & 0 & 0 \\ -\alpha_2\sigma_d^2 & \sigma_m^2+\alpha_2^2\sigma_d^2 & 0 & 0 \\ 0 & 0 & \sigma_d^{*2}+\sigma_c^{*2} & -\alpha_2\sigma_d^{*2} \\ 0 & 0 & -\alpha_2^*\sigma_d^{*2} & \sigma_m^{*2}+\alpha_2^{*2}\sigma_d^{*2} \end{bmatrix}^{-1} \begin{bmatrix} S_{gt} \\ S_{mt} \\ S_{gt}^* \\ S_{mt}^* \end{bmatrix}.$$

Solving further yields:

$$E_t\varepsilon_{mt} = \varepsilon_{mt} - \alpha_2 \left[\theta_d \varepsilon_{dt} - \theta_c \varepsilon_{ct} + \frac{\theta_m \varepsilon_{mt}}{\alpha_2} \right], \tag{16a}$$

[7]The matrix expression for conditional expectations is based upon the well-known Bayesian formula for conditional expectations. In the expression the first matrix on the right-hand side contains the covariances of the disturbances and signals, and the second matrix is the inverse of the variance–covariance matrix of signals. Alternatively, the conditional expectations can be computed from the projection formula for expectations of a given disturbance ε_t, formed conditionally on an information set consisting of the signals S_t and Ω_t, where Ω_t may be a set of other signals [see Sargent (1979, pp. 208–209)].

$$\mathrm{E}_t\varepsilon_{dt}=\varepsilon_{dt}-\left[\theta_d\varepsilon_{dt}-\theta_c\varepsilon_{ct}+\frac{\theta_m\varepsilon_{mt}}{\alpha_2}\right], \tag{16b}$$

$$\mathrm{E}_t\varepsilon_{ct}=\varepsilon_{ct}+\left[\theta_d\varepsilon_{dt}-\theta_c\varepsilon_{ct}+\frac{\theta_m\varepsilon_{mt}}{\alpha_2}\right], \tag{16c}$$

$$\mathrm{E}_t\varepsilon^*_{mt}=\varepsilon^*_{mt}-\alpha^*_2\left[\theta^*_d\varepsilon^*_{dt}-\theta^*_c\varepsilon^*_{ct}+\frac{\theta^*_m\varepsilon^*_{mt}}{\alpha^*_2}\right], \tag{16d}$$

$$\mathrm{E}_t\varepsilon^*_{dt}=\varepsilon^*_{dt}-\left[\theta^*_d\varepsilon^*_{dt}-\theta^*_c\varepsilon^*_{ct}+\frac{\theta^*_m\varepsilon^*_{mt}}{\alpha^*_2}\right], \tag{16e}$$

$$\mathrm{E}_t\varepsilon^*_{ct}=\varepsilon^*_{ct}+\left[\theta^*_d\varepsilon^*_{dt}-\theta^*_c\varepsilon^*_{ct}+\frac{\theta^*_m\varepsilon^*_{mt}}{\alpha^*_2}\right], \tag{16f}$$

where

$$\theta_d=\frac{\sigma_c^2\sigma_m^2}{\Delta},\qquad \theta_c=\frac{\sigma_d^2\sigma_m^2}{\Delta},\qquad \theta_m=\frac{\alpha_2^2\sigma_d^2\sigma_c^2}{\Delta},$$

$$\theta^*_d=\frac{\sigma_c^{*2}\sigma_m^{*2}}{\Delta^*},\qquad \theta^*_c=\frac{\sigma_d^{*2}\sigma_m^{*2}}{\Delta^*},\qquad \theta^*_m=\frac{\alpha_2^{*2}\sigma_d^{*2}\sigma_c^{*2}}{\Delta^*},$$

$$\Delta=\sigma_m^2\sigma_d^2+\sigma_m^2\sigma_c^2+\alpha_2^2\sigma_d^2\sigma_c^2,\qquad \Delta^*=\sigma_m^{*2}\sigma_d^{*2}+\sigma_m^{*2}\sigma_c^{*2}+\alpha_2^{*2}\sigma_d^{*2}\sigma_c^{*2},$$

$$\theta_d+\theta_c+\theta_m=1,\qquad \theta^*_d+\theta^*_c+\theta^*_m=1,\qquad 0\leqq\theta_i,\quad \theta^*_i\leqq 1,$$

and the σ^2 denote the absolute variance of individual shocks. Expressions (16a)–(16f) relate the conditional expectations of current shocks to their actual realizations. The θ (θ^*) parameters, representing the relative variances of individual domestic (foreign) shocks, reflect the noisiness of market conditions and hence the degree of confusion by agents about the shocks they cannot directly observe. Thus, for example, θ_d indicates that confusion about real domestic demand disturbances is high when the variances of domestic cost and money shocks are relatively large since, in that case, market conditions primarily reflect fluctuations due to cost and money disturbances, and reveal relatively little about demand conditions. Note that perceptions of domestic disturbances depend only on domestic conditions, and not on foreign conditions in this particular model. The reason is that under flexible exchange rates the signals observed by agents enable them to distinguish between domestic and foreign shocks. Thus, under flexible rates confusion about domestic shocks is insulated from further confusion due to foreign shocks. In the extension presented in section 5 these results are modified when additional interactions between the goods markets are considered.

In the absence of any confusion about current shocks, the θ and θ^* parameters equal zero. In general, confusion will exist and agents will not fully perceive all shocks. Expression (16b), for example, says that, with imperfect information, expectations of real domestic demand shocks depend on domestic money (and cost) shocks. More specifically, positive money shocks result in lower expectations of demand shocks. The effect of a given money shock on perceptions of real demand disturbances is magnified the smaller are the relative variances of money disturbances (the greater is θ_m). Expectations of cost and money shocks may be interpreted similarly.

To solve explicitly for the B coefficients in (15), first use (16a)–(16f) in the expectation of its forward-dated equivalent to form $E_t q_{t+1}$ and then substitute the resulting expression in (9). Rearranging and equating coefficients term by term with (15) results in the expressions in table 1.

In either the case of perfect information, characterized when the relative confusion parameters, θ and θ^*, are equal to zero, or the case when the serial correlation of real demand and cost disturbances are equal (implying $R_d = R_c, R_d^* = R_c^*$), the real exchange rate depends only on real demand and cost shocks, and not on current or lagged money shocks ($B_m = B_m^* = B_m^\varepsilon = B_m^{\varepsilon *} = 0$). In the case of imtperfect information and serial correlation differences, current domestic and foreign money supply shocks will influence the real exchange rate. Lagged money disturbances have no effect since it has been assumed that agents know all past disturbances with a one-period lag.

Note that the sign of the exchange rate response depends on the relative magnitudes of demand and cost serial-correlation parameters. If domestic demand disturbances persist more (less) strongly than cost disturbances, then $R_d - R_c > 0$ ($R_d - R_c < 0$) and a positive domestic money supply shock causes a real domestic currency depreciation (appreciation). It should also be noted that if $R_d - R_c$ and $R_d^* - R_c^*$ have the same sign, then domestic and foreign money supply shocks affect the real exchange rate in opposite directions.

The possibility that a positive domestic monetary shock may cause a real domestic currency appreciation may seem surprising, but the explanation can be found in the nature of each country's goods and money market signals. Assume, for example, that a money shock occurs which causes an underestimate of the current demand shock ($E_t d_t < d_t$). Because the goods market signal reflects the *sum* of real demand and cost shocks, any underestimate of the demand shock implies a corresponding overestimate of the cost shock. The effect of these misperceptions on the current exchange rate, working

Table 1
Real exchange rate response coefficients – flexible exchange rate.

$$q_t = \bar{q} + B_m m_{t-1} + B_d d_{t-1} + B_c c_{t-1} + B_m^* m_{t-1}^* + B_d^* d_{t-1}^* + B_c^* c_{t-1}^* + B_m^\varepsilon \varepsilon_{mt} + B_d^\varepsilon \varepsilon_{dt} + B_c^\varepsilon \varepsilon_{ct} + B_m^{\varepsilon *} \varepsilon_{mt}^* + B_d^{\varepsilon *} \varepsilon_{dt}^* + B_c^{\varepsilon *} \varepsilon_{ct}^*$$

$$\bar{q} = H_0/(1-H_1) > 0$$

$$B_m = 0, \quad B_d = H_3 R_d > 0, \quad B_c = H_3 R_c > 0$$

$$B_m^* = 0, \quad B_d^* = -H_2 R_d^* < 0, \quad B_c^* = -H_2 R_c^* < 0$$

$$B_m^\varepsilon = -\frac{\theta_m (R_d - R_c) H_3 H_1}{a_2} \gtrless 0$$

$$B_d^\varepsilon = \frac{H_3 R_d}{\rho_d} - \theta_d (R_d - R_c) H_3 H_1 > 0$$

$$B_c^\varepsilon = \frac{H_3 R_c}{\rho_c} + \theta_c (R_d - R_c) H_3 H_1 > 0$$

$$B_m^{\varepsilon *} = \frac{\theta_m^* (R_d^* - R_c^*) H_2 H_1}{\alpha_2^*} \gtrless 0$$

$$B_d^{\varepsilon *} = -\frac{H_2 R_d^*}{\rho_d^*} + \theta_d^* (R_d^* - R_c^*) H_2 H_1 < 0$$

$$B_c^{\varepsilon *} = -\frac{H_2 R_c^*}{\rho_c^*} - \theta_c^* (R_d^* - R_c^*) H_2 H_1 < 0$$

$$R_d = \frac{\rho_d}{1 - H_1 \rho_d}, \quad R_c = \frac{\rho_c}{1 - H_1 \rho_c}, \quad R_d^* = \frac{\rho_d^*}{1 - H_1 \rho_d^*}, \quad R_c^* = \frac{\rho_c^*}{1 - H_1 \rho_c^*}$$

through expectations on the future exchange rate, depends on the relative persistence of shocks. If cost shocks persist more strongly, then the effect on real exchange rate expectations of the overestimate of the cost shock dominates that of the underestimate of the demand shock. As a result, a domestic real appreciation is expected, and the real interest rate falls. This induces an excess demand for domestic goods and consequently a current appreciation of the domestic currency.[8]

Most importantly, note that the larger is σ_m^2 (σ_m^{*2}) and hence the smaller is

[8]In empirical studies of monetary innovations under flexible rates, such as that of Engel and Frankel (1984), it has been observed that an unanticipated increase in the money supply causes a real interest rate increase and an appreciation of the domestic currency. In our model, a real interest rate increase occurs in combination with a real and nominal depreciation after a monetary shock if the serial correlation of demand disturbances exceeds that of cost disturbances. On the other hand, a real appreciation occurs in combination with a fall in the real interest rate under the reverse condition noted in the text. Engel and Frankel explain their results within a sticky-price model by assuming expectations of a reversal of monetary policy.

θ_m (θ_m^*) and the confusion about domestic (foreign) money supply shocks, the less the absolute response of the real exchange rate to domestic (foreign) money supply shocks, B_m^ε ($B_m^{\varepsilon *}$), given the variance of real shocks. Moreover, for reasons noted above, the response of q to ε_m (ε_m^*) is independent of θ_m^* (θ_m).[9]

These results are summarized by the following proposition:

Proposition 1. Under flexible exchange rates, the absolute magnitude of the adjustment of the real exchange rate to an unanticipated domestic (foreign) money supply shock is (a) *decreasing in the variance of the domestic (foreign) money supply shock, given the variance of real shocks, and* (b) *independent of the variance of the foreign (domestic) money supply shock.*

In section 5 we show that the latter part of this proposition is modified if additional interactions exist among the goods markets. We conclude this section by noting that the response of q to current real domestic and foreign shocks also depends on the degree of confusion about these shocks and on the serial correlation parameters, as discussed above.

4. Money markets and equilibrium under fixed exchange rates

In this section we assume that monetary authorities fix or manage the nominal exchange rate, and analyze the real effects of unanticipated monetary and real shocks. We focus on the perfectly fixed exchange rate case in the formal analysis, but it may be generalized to any regime under which the central bank intervenes according to a rule involving only observable variables. Under these conditions, the exchange rate does not contain information about unobservable disturbances, and central bank intervention is equivalent to a fixed exchange rate regime in terms of informativeness.[10]

Under fixed exchange rates, a distinction must be made between changes in the money supply that are due to local credit (m_t, m_t^*) and to international reserve movements associated with foreign exchange intervention (and also to the money multiplier, which is ignored here). We continue to assume that the local components of the money supplies follow the exogenous processes described in (12). The international reserves component of the money supply

[9]Note that although confusion about disturbances in each country ($\varepsilon_i, \varepsilon_i^*$) is independent of disturbances in the other, the real interest rate and output levels in each country are not insulated from monetary disturbances in the other since, as table 1 shows, q depends on ε_m^*. Intuitively, the real exchange rate depends on foreign, as well as domestic, shocks.

[10]This presumes also that agents know the parameters of the intervention rule followed by monetary authorities, and information is homogeneous among agents. This last assumption contrasts our model with the analysis of, for example, Flood and Hodrick (1985a), who assume heterogeneous information among agents. In their model, 'asset-market specialists', but not 'goods-market specialists', know all current disturbances.

responds endogenously to disturbances to foreign as well as domestic money supply and demand. This implies that the equilibrium conditions (13) and (14) are no longer independent, and hence that they do not provide independent money market signals. Rather there is a single world money signal obtained from the world money market equilibrium condition.

This discussion implies that the distinguishing criterion between flexible and fixed regimes is not the degree of flexibility of the exchange rate per se, but the extent to which there are unperceived international reserve movements. In the absence of fully announced intervention actions, agents lack the ability to separate out the effects of foreign conditions on the market-clearing variables they can observe.[11] In our model it is assumed that reserve movements are observed with a one-period lag and the (nominal) exchange rate is perfectly fixed.

The world money supply consists of the sum of international reserve holdings (assumed denominated in domestic currency) and of the locally-created money supplies in the two countries, implying that the log of the world money supply can be expressed in the following way:

$$m_t^w = [w_1(1-w_2) + w_1^*(1-w_2^*)]x_t^w + w_1 w_2 m_t + w_1^* w_2^* m_t^*, \tag{17}$$

where m_t^w and x_t^w are (the logs of) total world money and international reserves, respectively; w_1 and w_1^* denote the share of world money held in each country, $w_1 + w_1^* = 1$; and w_2 and w_2^* denote the share of locally-created money in the money supply held in each country.[12] The (fixed) nominal level of the exchange rate is normalized to 1, implying $s=0$. Both the locally-created money supplies, m_t and m_t^*, and international reserves are unobservable in the current period.

The equilibrium condition in the world money market is:

$$m_t^w = w_1(p_t + \alpha_2 y_t - \alpha_1 i_t) + w_1^*(p_t^* + \alpha_2^* y_t^* - \alpha_1^* i_t^*). \tag{18}$$

For simplicity, it is assumed that there is no growth in total international

[11]Flood and Hodrick (1985a) show that if monetary authorities determine the money supply in relation to the level of international reserves and if they announce current foreign exchange intervention, rendering this variable observable to private agents, then, as in our model, the information content of the money market signal (g_{1t} in their model) is identical to that under a free float.

[12]Specifically: $w_1 = (M+X)/M^w$, $w_1^* = (M^* + X^*)/M^w$, $w_2 = M/(X+M)$ and $w_2^* = M^*(X^* + M^*)$, where capital letters denote levels in natural units of their lower case analogues.

reserves, i.e. $x_t^w=0$.[13] Expressions (17) and (18) together with (3)–(8) and (12) then yield the following relation for the domestic price level:

$$\begin{aligned}p_t(1+w_1\alpha_1+w_1^*\alpha_1^*)=w_1\{&w_2(\rho_m m_{t-1}+\varepsilon_{mt})-\alpha_2 b_0+(\alpha_2 b_1+\alpha_1)r_t\\&+b_2\alpha_2 q_t-\alpha_2(\rho_d d_{t-1}+\varepsilon_{dt})+\alpha_1 \mathrm{E}_t p_{t+1}\}\\&+w_1^*\{w_2^*(\rho_m^* m_{t-1}^*+\varepsilon_{mt}^*)-\alpha_2^* b_0^*+(\alpha_2^* b_1^*+\alpha_1^*)r_t\\&+(1-\alpha_2^*(b_2^*+b_1^*))q_t\\&-\alpha_2^*(\rho_d^* d_{t-1}^*+\varepsilon_{dt}^*)+\alpha_2^* b_1^* \mathrm{E}_t q_{t+1}+\alpha_1^* \mathrm{E}_t p_{t+1}\}. \quad (19)\end{aligned}$$

Under the usual knowledge assumptions, (19) yields the money market signal $S_{Mt}=w_1(w_2\varepsilon_{mt}-\alpha_2\varepsilon_{dt})+w_1^*(w_2^*\varepsilon_{mt}^*-\alpha_2^*\varepsilon_{dt}^*)$. Note that S_M is a weighted average of the domestic and foreign market signals that were obtained under flexible exchange rates. As long as the serial correlations of money supply and demand disturbances differ between the two countries, then there is value to agents in being able to distinguish between the country of origin of disturbances.

Analogously to the flexible rate case, agents' expectations of the current shocks, conditional on the signals S_g, S_g^*, and S_M, can be determined by solving:

$$\begin{bmatrix}\mathrm{E}_t\varepsilon_{mt}\\ \mathrm{E}_t\varepsilon_{dt}\\ \mathrm{E}_t\varepsilon_{ct}\\ \mathrm{E}_t\varepsilon_{mt}^*\\ \mathrm{E}_t\varepsilon_{dt}^*\\ \mathrm{E}_t\varepsilon_{ct}^*\end{bmatrix}=\begin{bmatrix}0 & w_1w_2\sigma_m^2 & 0\\ \sigma_d^2 & -w_1\alpha_2\sigma_d^2 & 0\\ \sigma_c^2 & 0 & 0\\ 0 & w_1^*w_2^*\sigma_m^{*2} & 0\\ 0 & -w_1^*\alpha_2^*\sigma_d^{*2} & \sigma_d^{*2}\\ 0 & 0 & \sigma_c^{*2}\end{bmatrix}$$

$$\times\begin{bmatrix}\sigma_d^2+\sigma_c^2 & -w_1\alpha_2\sigma_d^2 & 0\\ -w_1\alpha_2\sigma_d^2 & \begin{array}{c}w_1^2(w_2^2\sigma_m^2+\alpha_2^2\sigma_d^2)\\ +w_1^{*2}(w_2^*\sigma_m^{*2}+\alpha_2^{*2}\sigma_d^{*2})\end{array} & -w_1^*\alpha_2^*\sigma_d^{*2}\\ 0 & -w_1^*\alpha_2^*\sigma_d^{*2} & \sigma_d^{*2}+\sigma_c^{*2}\end{bmatrix}^{-1}\begin{bmatrix}S_{gt}\\ S_{Mt}\\ S_{gt}^*\end{bmatrix},$$

[13]Note that with $x_t^w=0$, (17) and (18) imply that $w_1(w_2m_t-m_t^d)=w_1^*(m_t^{*d}-w_2^*m_t^*)$, i.e. an excess supply of locally-created money in the domestic country equals the excess demand for money abroad, where m_t^d and m_t^{*d} denote the demand for money domestically and abroad, respectively. The excess supply of money domestically corresponds to an international reserve outflow.

which implies:

$$E_t\varepsilon_{mt}=\varepsilon_{mt}-e_2\gamma^*\left[\theta'_d\varepsilon_{dt}-\theta'_c\varepsilon_{ct}+\frac{\theta'_m\varepsilon_{mt}}{e_2}\right]-\gamma\varepsilon_{mt}$$

$$-e_0e_2\gamma^*(\theta'_d+\theta'_c)\left[\Phi^*_d\varepsilon^*_{dt}-\Phi^*_c\varepsilon^*_{ct}-\frac{\varepsilon^*_{mt}}{e^*_2}\right], \tag{20a}$$

$$E_t\varepsilon_{dt}=\varepsilon_{dt}-\gamma^*\left[\theta'_d\varepsilon_{dt}-\theta'_c\varepsilon_{ct}+\frac{\theta'_m\varepsilon_{mt}}{e_2}\right]-\gamma[\Phi_d\varepsilon_{dt}-\Phi_c\varepsilon_{ct}]$$

$$+e_0\gamma^*\theta'_m\left[\Phi^*_d\varepsilon^*_{dt}-\Phi^*_c\varepsilon^*_{ct}-\frac{\varepsilon^*_{mt}}{e^*_2}\right], \tag{20b}$$

$$E_t\varepsilon_{ct}=\varepsilon_{ct}+\gamma^*\left[\theta'_d\varepsilon_{dt}-\theta'_c\varepsilon_{ct}+\frac{\theta'_m\varepsilon_{mt}}{e_2}\right]+\gamma[\Phi_d\varepsilon_{dt}-\Phi_c\varepsilon_{ct}]$$

$$-e_0\gamma^*\theta'_m\left[\Phi^*_d\varepsilon^*_{dt}-\Phi^*_c\varepsilon^*_{ct}-\frac{\varepsilon^*_{mt}}{e^*_2}\right], \tag{20c}$$

$$E_t\varepsilon^*_{mt}=\varepsilon^*_{mt}-e^*_2\gamma\left[\theta^{*\prime}_d\varepsilon^*_{dt}-\theta^{*\prime}_c\varepsilon^*_{ct}+\frac{\theta^{*\prime}_m\varepsilon^*_{mt}}{e^*_2}\right]-\gamma^*\varepsilon^*_{mt}$$

$$-e^*_0e^*_2\gamma(\theta^{*\prime}_d+\theta^{*\prime}_c)\left[\Phi_d\varepsilon_{dt}-\Phi_c\varepsilon_{ct}-\frac{\varepsilon_{mt}}{e_2}\right], \tag{20d}$$

$$E_t\varepsilon^*_{dt}=\varepsilon^*_{dt}-\gamma\left[\theta^{*\prime}_d\varepsilon^*_{dt}-\theta^{*\prime}_c\varepsilon^*_{ct}+\frac{\theta^{*\prime}_m\varepsilon^*_{mt}}{e^*_2}\right]-\gamma^*[\Phi^*_d\varepsilon^*_{dt}-\Phi^*_c\varepsilon^*_{ct}]$$

$$+e^*_0\gamma\theta^{*\prime}_m\left[\Phi_d\varepsilon_{dt}-\Phi_c\varepsilon_{ct}-\frac{\varepsilon_{mt}}{e_2}\right], \tag{20e}$$

$$\mathrm{E}_t\varepsilon^*_{ct} = \varepsilon^*_{ct} + \gamma\left[\theta^{*\prime}_d\varepsilon^*_{dt} - \theta^{*\prime}_c\varepsilon^*_{ct} + \frac{\theta^{*\prime}_m\varepsilon^*_{mt}}{e^*_2}\right] + \gamma^*[\Phi^*_d\varepsilon^*_{dt} - \Phi^*_c\varepsilon^*_{ct}]$$

$$-e^*_0\gamma\theta^{*\prime}_m\left[\Phi_d\varepsilon_{dt} - \Phi_c\varepsilon_{ct} - \frac{\varepsilon_{mt}}{e_2}\right], \tag{20f}$$

where

$$\theta'_d = \frac{\sigma_c^2\sigma_m^2 w_2^2}{\Delta'}, \qquad \theta'_c = \frac{\sigma_d^2\sigma_m^2 w_2^2}{\Delta'}, \qquad \theta'_m = \frac{\alpha_2^2\sigma_d^2\sigma_c^2}{\Delta'},$$

$$\theta^{*\prime}_d = \frac{\sigma^{*2}_c\sigma^{*2}_m w^{*2}_2}{\Delta^{*\prime}}, \qquad \theta^{*\prime}_c = \frac{\sigma^{*2}_d\sigma^{*2}_m w^{*2}_2}{\Delta^{*\prime}}, \qquad \theta^{*\prime}_m = \frac{\alpha^{*2}_2\sigma^{*2}_d\sigma^{*2}_c}{\Delta^{*\prime}},$$

$$\gamma^* = \frac{w_1^2(\sigma^{*2}_d + \sigma^{*2}_c)\Delta'}{\Lambda}, \quad \gamma = \frac{w^{*2}_1(\sigma_d^2 + \sigma_c^2)\Delta^{*\prime}}{\Lambda}, \quad \gamma + \gamma^* = 1, \quad 0 \leqq \gamma, \quad \gamma^* \leqq 1$$

$$\Phi_d = \frac{\sigma_c^2}{\sigma_c^2 + \sigma_d^2}, \qquad \Phi_c = \frac{\sigma_d^2}{\sigma_c^2 + \sigma_d^2},$$

$$\Phi^*_d = \frac{\sigma^{*2}_c}{\sigma^{*2}_c + \sigma^{*2}_d}, \qquad \Phi^*_c = \frac{\sigma^{*2}_d}{\sigma^{*2}_c + \sigma^{*2}_d},$$

$$\Lambda = w_1^2(\sigma^{*2}_d + \sigma^{*2}_c)\Delta' + w^{*2}_1(\sigma_d^2 + \sigma_c^2)\Delta^{*\prime}$$

$$\Delta' = \sigma_m^2\sigma_d^2 w_2^2 + \sigma_m^2\sigma_c^2 w_2^2 + \alpha_2^2\sigma_d^2\sigma_c^2,$$

$$\Delta^{*\prime} = \sigma^{*2}_m\sigma^{*2}_d w^{*2}_2 + \sigma^{*2}_m\sigma^{*2}_c w^{*2}_2 + \alpha^{*2}_2\sigma^{*2}_d\sigma^{*2}_c,$$

$$e_0 = \frac{\alpha^*_2 w^*_1}{\alpha_2 w_1}, \qquad e^*_0 = \frac{\alpha_2 w_1}{\alpha^*_2 w^*_1}, \qquad e_0 = \frac{1}{e^*_0}, \qquad e_2 = \frac{\alpha_2}{w_2}, \qquad e^*_2 = \frac{\alpha^*_2}{w^*_2}.$$

In addition to the θ' parameters, which have the same interpretation as the θ parameters in (16a)–(16f), (20a)–(20f) contain γ parameters representing relative world confusion about local-money shocks. For example, γ^* reflects the degree of world confusion about foreign money shocks. γ^* (γ) is decreasing in the variance of foreign (domestic) unanticipated money and increasing in other variances.

In contrast to the flexible rate case, perceptions of domestic shocks depend on foreign as well as on domestic shocks because agents cannot distinguish between domestic and foreign money shocks. Under fixed exchange rates, local confusion is not insulated from confusion about foreign disturbances. Note also that the effects of a given domestic (foreign) money supply shock on perceptions of domestic real demand and costs shocks is magnified the greater is world confusion about foreign (domestic) money, i.e. the greater is γ^* (γ).

The real exchange rate response coefficients under a fixed rate regime can be determined by substituting (20a)–(20f) in the implicit expression for $E_t q_{t+1}$, inserting the resulting expression in (9), and comparing coefficient terms with (15). The resulting expression's coefficients, denoted with prime signs to distinguish them from those for the flexible regime, are presented in table 2. Note that the coefficients for lagged disturbances are the same as in the flexible rate case.

A number of interesting differences between the fixed and flexible exchange rate cases may be seen by a comparison of tables 1 and 2. A comparison of coefficients for money shocks shows that $B_m^{\varepsilon*\prime} = B_m^{\varepsilon\prime}(w_1^* w_2^*)/(w_1 w_2)$ and $B_m^{\varepsilon\prime} = w_2\gamma^*(\theta_m'/\theta_m)B_m^{\varepsilon} + w_2(w_1/w_1^*)\gamma(\theta_m^{*\prime}/\theta_m^*)B_m^{\varepsilon*}$. The fixed exchange rate adjustment coefficients are weighted averages of those under flexible rates.

These expressions point to four factors that differentially influence real exchange rate adjustment under fixed and floating rates. First, the degree of local confusion about money shocks is relatively less under fixed rates, since $\theta_m'/\theta_m < 1$ and $\theta_m^{*\prime}/\theta_m^* < 1$. These ratios approach unity as the share of international reserves in each country's money supply falls (i.e. as w_2 and w_2^* tend to 1). Second, under flexible rates, with the symmetry assumptions, $H_2 = H_3$ and $R_d - R_c = R_d^* - R_c^*$, domestic and foreign money shocks influence q in opposite directions while under fixed rates the shocks affect q in the same direction. Third, since the effect of a money shock on the real exchange rate under fixed rates is a weighted average of those under flexible rates, for a given level of world money confusion (γ, γ^*) the real exchange rate effect of a monetary shock is generally smaller under fixed rates than under flexible rates. The reason is that a money shock's origin is unknown under fixed rates and confused with both domestic and foreign real shocks which have opposite effects on the real exchange rate. Fourth, under fixed rates the world integration of money markets diversifies confusion about money (since $\gamma < 1, \gamma^* < 1$) and in turn reduces the exchange rate effect of money shocks in each country.

For comparison with Proposition 1, we investigate how exchange rate adjustment depends on money supply variances. Observe that the absolute magnitude of the response of the real exchange rate to a money supply of given origin depends under symmetry conditions on $\gamma^*\theta_m' - \gamma\theta_m^{*\prime}/e_0$, the absolute value of which is decreasing in the variance of the locally-created

Table 2
Real exchange rate response coefficients – fixed exchange rate.

$$q_t = \bar{q} + B_m m_{t-1} + B_d d_{t-1} + B_c c_{t-1} + B_m^* m_{t-1}^* + B_d^* d_{t-1}^* + B_c^* c_{t-1}^* + B_m^{\varepsilon\prime} \varepsilon_{mt} + B_d^{\varepsilon\prime} \varepsilon_{dt} + B_c^{\varepsilon\prime} \varepsilon_{ct} + B_m^{\varepsilon*\prime} \varepsilon_{mt}^* + B_d^{\varepsilon*\prime} \varepsilon_{dt}^* + B_c^{\varepsilon*\prime} \varepsilon_{ct}^*$$

$$\bar{q} = H_0/(1-H_1) > 0$$

$$B_m = 0, \qquad B_d = H_3 R_d > 0, \qquad B_c = H_3 R_c > 0$$

$$B_m^* = 0, \qquad B_d^* = -H_2 R_d^* < 0, \qquad B_c^* = -H_2 R_c^* < 0$$

$$B_m^{\varepsilon\prime} = -\left[\gamma^* \theta_m'(R_d - R_c) H_3 - \frac{\gamma \theta_m^{*\prime}(R_d^* - R_c^*) H_2}{e_0}\right]\left(\frac{H_1}{e_2}\right) \lesseqgtr 0$$

$$B_d^{\varepsilon\prime} = \frac{H_3 R_d}{\rho_d} - \left[(\gamma^* \theta_d' + \gamma \Phi_d)(R_d - R_c) H_3 + \frac{\gamma \theta_m^{*\prime} \Phi_d (R_d^* - R_c^*) H_2}{e_0}\right] H_1 \lesseqgtr 0$$

$$B_c^{\varepsilon\prime} = \frac{H_3 R_c}{\rho_c} + \left[(\gamma^* \theta_c' + \gamma \Phi_c)(R_d - R_c) H_3 + \frac{\gamma \theta_m^{*\prime} \Phi_c (R_d^* - R_c^*) H_2}{e_0}\right] H_1 \gtrless 0$$

$$B_m^{\varepsilon*\prime} = -\left[\frac{\gamma^* \theta_m'(R_d - R_c) H_3}{e_0^*} - \gamma \theta_m^{*\prime}(R_d^* - R_c^*) H_2\right]\left(\frac{H_1}{e_2^*}\right) \lesseqgtr 0$$

$$B_d^{\varepsilon*\prime} = -\frac{H_2 R_d^*}{\rho_d^*} + \left[\frac{\gamma^* \theta_m' \Phi_d^* (R_d - R_c) H_3}{e_0^*} + (\gamma \theta_d^{*\prime} + \gamma^* \Phi_d^*)(R_d^* - R_c^*) H_2\right] H_1 \lesseqgtr 0$$

$$B_c^{\varepsilon*\prime} = -\frac{H_2 R_c^*}{\rho_c^*} - \left[\frac{\gamma^* \theta_m' \Phi_c^* (R_d - R_c) H_3}{e_0^*} + (\gamma \theta_c^{*\prime} + \gamma^* \Phi_c^*)(R_d^* - R_c^*) R_2\right] H_1 \lesseqgtr 0$$

$$R_d = \frac{\rho_d}{1 - H_1 \rho_d}, \qquad R_c = \frac{\rho_c}{1 - H_1 \rho_c}, \qquad R_d^* = \frac{\rho_d^*}{1 - H_1 \rho_d^*}, \qquad R_c^* = \frac{\rho_c^*}{1 - H_1 \rho_c^*}$$

money supply in *either* country ($\sigma_m^2, \sigma_m^{*2}$). Under flexible rates, the response of q to domestic money shocks was seen to be independent of the variance of foreign money supply shocks.

This discussion can be summarized in the following proposition for the fixed exchange rate case:

Proposition 2. Under fixed exchange rates, the absolute magnitude of the adjustment of the real exchange rate to an unanticipated local-domestic (local-foreign) money supply shock is (a) *generally smaller than under flexible rates,* (b) *decreasing in the variance of both domestic and foreign money supply shocks, given the variance of real shocks, and* (c) *is less sensitive to changes in the local-domestic (local-foreign) money supply variance than under flexible exchange rates.*

We conclude this section by turning to Kimbrough's argument that a fixed rate regime is 'less informative' than a flexible regime about monetary and real disturbances. In Kimbrough's small-country model, 'less informative' is interpreted to mean that the variance of output around its full information equilibrium level, i.e. the level prevailing when all current shocks are known, is larger under a fixed exchange rate regime than with flexible exchange rates. In our model, 'informativeness' in Kimbrough's sense can be measured by the variance in the real exchange rate that is attributable to unanticipated disturbances.

To examine the relative variability of the real exchange rate under different regimes, we denote by σ_{qm}^2 the variance of the real exchange rate attributable to domestic and foreign unanticipated money shocks under flexible rates. Expression (15), together with the assumption $\sigma_m^2 = \sigma_m^{*2}$, imply:

$$\sigma_{qm}^2 = [(B_m^\varepsilon)^2 + (B_m^{\varepsilon *})^2]\sigma_m^2. \tag{21}$$

The analogous expression under fixed rates ($\sigma_{qm}'^2$) is:

$$\sigma_{qm}'^2 = [w_2\gamma^*(\theta_m'/\theta_m)B_m^\varepsilon + w_1\gamma(\theta_m^{*\prime}/\theta_m^*)B_m^{\varepsilon *}]^2\left[1+\left(\frac{w_1^* w_2^*}{w_1 w_2}\right)^2\right]\sigma_m^2. \tag{22}$$

Under the symmetry conditions above, $\sigma_{qm}'^2$ is less than σ_{qm}^2. This implication of a fixed exchange rate regime seemingly contradicts Kimbrough's argument that flexible exchange rates are more informative. However, the discussion above refers to relative exchange rate variability attributable only to unanticipated money shocks; it does not take account of the exchange rate regime on the variability that is conditional on unanticipated real shocks. In fact, from inspection of the relevant coefficients in tables 1 and 2 it can be shown that exchange rate variability attributable to real shocks is larger under fixed rates since those in the fixed rate case involve more terms. Moreover, by somewhat tedious manipulations, it can be shown that under a fixed exchange rate regime the variance of real exchange rate (and of output) attributable to all unanticipated disturbances, real as well as monetary, is larger than under flexible rates. This implies that Kimbrough's result holds in our two-country model as well.[14]

The implications of our analysis also accord partially with the literature on optimal exchange rate intervention which generally argues that a fixed rate regime is more advantageous when money shocks dominate real shocks.[15] In

[14]The proof can be obtained from the authors upon request. Flood and Hodrick (1986) show that the conditional variance of the real exchange rate may be more or less under flexible rates.

[15]See, for example, Boyer (1978), Henderson (1979), Daniel (1985), and Glick and Hutchison (1989).

our framework, fixed rates are more informative about monetary shocks and less informative about real shocks. Moreover, since an increase in the relative variance of money shocks tends to reduce confusion about the effects of money shocks, fixed rates are informationally less inferior as money shocks become more dominant.

5. Extensions

In this section we discuss possible extensions to the model. We focus on the analysis of whether Propositions 1 and 2 generalize to a case in which the goods and money market signals in each country are less insulated from the effects of confusion about disturbances in the other. We do this by introducing foreign demand disturbances directly into each country's aggregate demand equation (3). Thereafter, we briefly discuss other possible extensions.

The direct demand interactions are introduced into eqs. (3) by adding the terms $b_3 d_t^*$ and $b_3^* d_t$, respectively. The b_3 and b_3^* parameters, $0 \leqq b_3 \leqq 1$ and $0 \leqq b_3^* \leqq 1$, reflect the extent to which foreign aggregate demand disturbances affect local aggregate demand in each country. To facilitate a solution, we define $h_t = d_t + b_3 d_t^*$ and $h_t^* = d_t^* + b_3^* d_t$ as composites of the domestic and foreign demand shocks in the two countries.

It is straightforward to observe that in solving for (9) and (10) and subsequently (13) and (14) for the flexible case and (19) for the fixed case, h_t appears in place of d_t and h_t^* in place of d_t^*, respectively. It follows that the goods market signals become $S_{gt} = \varepsilon_{ht} + \varepsilon_{ct}$ and $S_{gt}^* = \varepsilon_{ht}^* + \varepsilon_{ct}^*$, while, in the flexible rate case, the money market signals are $S_{mt} = \varepsilon_{mt} - \alpha_2 \varepsilon_{ht}$ and $S_{mt}^* = \varepsilon_{mt}^* - \alpha_2^* \varepsilon_{ht}^*$, and in the fixed rate case $S_{Mt} = w_1(w_2 \varepsilon_{mt} - \alpha_2 \varepsilon_{ht}) + w_1^*(w_2^* \varepsilon_m^* - \alpha_2^* \varepsilon_{ht}^*)$.

The projection system for computing conditional expectations in the flexible rate case is now:

$$\begin{bmatrix} E_t\varepsilon_{mt} \\ E_t\varepsilon_{ht} \\ E_t\varepsilon_{ct} \\ E_t\varepsilon_{mt}^* \\ E_t\varepsilon_{ht}^* \\ E_t\varepsilon_{ct}^* \end{bmatrix} = \begin{bmatrix} 0 & \sigma_m^2 & 0 & 0 \\ \sigma_h^2 & -\alpha_2\sigma_h^2 & \sigma_{hh}^* & -\alpha_2^*\sigma_{hh}^* \\ \sigma_c^2 & 0 & 0 & 0 \\ 0 & 0 & 0 & \sigma_m^{*2} \\ \sigma_{hh}^* & -\alpha_2\sigma_{hh}^* & \sigma_h^{*2} & -\alpha_2^*\sigma_h^{*2} \\ 0 & 0 & \sigma_c^{*2} & 0 \end{bmatrix}$$

$$\times \begin{bmatrix} \sigma_h^2+\sigma_c^2 & -\alpha_2\sigma_h^2 & \sigma_{hh}^* & -\alpha_2^*\sigma_{hh}^* \\ -\alpha_2\sigma_h^2 & \sigma_m^2+\alpha_2^2\sigma_h^2 & -\alpha_2\sigma_{hh}^* & \alpha_2\alpha_2^*\sigma_{hh}^* \\ \sigma_{hh}^* & -\alpha_2\sigma_{hh}^* & \sigma_h^{*2}+\sigma_c^{*2} & -\alpha_2^*\sigma_h^{*2} \\ -\alpha_2^*\sigma_{hh}^* & \alpha_2\alpha_2^*\sigma_{hh}^* & -\alpha_2^*\sigma_h^{*2} & \sigma_m^{*2}+\alpha_2^{*2}\sigma_h^{*2} \end{bmatrix}^{-1} \begin{bmatrix} S_{gt} \\ S_{mt} \\ S_{gt}^* \\ S_{mt}^* \end{bmatrix},$$

where $\mathrm{Cov}(\varepsilon_h, \varepsilon_h^*) \equiv \sigma_{hh}^* = b_3 \sigma_d^{*2} + b_3^* \sigma_d^2$. Note that the variance–covariance matrix of signals is no longer block diagonal. The exchange rate projection system for the fixed rate case is not presented since it is affected in an analogous manner.

Skipping the tedious details, it can be shown under the symmetry assumptions $R_h - R_c = R_h^* - R_c^*$ and $H_3 = H_2$, for flexible rates, B_m^ε equals:

$$-\frac{[(\sigma_m^{*2} + \alpha_2^{*2}\sigma_c^{*2})(\sigma_h^2 \sigma_h^{*2} - (\sigma_{hh}^*)^2) + \sigma_c^{*2}\sigma_m^{*2}(\sigma_h^2 - \sigma_{hh}^*)]\alpha_2^2 \sigma_c^2 (R_h - R_c) H_3 H_1}{\{\alpha_2 \Omega\}}, \tag{23}$$

and for fixed rates, $B_m^{\varepsilon\prime}$ equals:

$$-\frac{\begin{array}{r}[(w_1\alpha_2\sigma_c^2 - w_1^*\alpha_2^*\sigma_c^{*2})(\sigma_h^{2*}\sigma_h^2 - (\sigma_{hh}^*)^2) + w_1\alpha_2\sigma_c^{*2}\sigma_c^2(\sigma_h^2 - \sigma_{hh}^*) \\ - w_1^*\alpha_2^*\sigma_c^2\sigma_c^{*2}(\sigma_h^{*2} - \sigma_{hh}^*)] w_1 \alpha_2 (R_h - R_c) H_3 H_1\end{array}}{\{e_2 \Omega'\}},$$

where

$$\Omega = \Delta\Delta^* - (\sigma_{hh}^*)^2(\sigma_m^2 + \alpha_2^2\sigma_c^2)(\sigma_m^{*2} + \alpha_2^{*2}\sigma_c^{*2}),$$

$$\Omega' = w_1^2 \Delta'(\sigma_h^{*2} + \sigma_c^{*2}) + w_1^{*2}\Delta^{*\prime}(\sigma_h^2 + \sigma_c^2) + 2\sigma_{hh}^* w_1 w_1^* \alpha_2 \alpha_2^* \sigma_c^2 \sigma_c^{*2}$$
$$- (\sigma_{hh}^*)^2 [w_1^2(w_2^2\sigma_m^2 + \alpha_2^2\sigma_c^2) + w_1^{*2}(w_2^{*2}\sigma_m^{*2} + \alpha_2^{*2}\sigma_c^{*2})],$$

and $\underline{\Delta}$, $\underline{\Delta}^*$, $\underline{\Delta}'$ and $\underline{\Delta}^{*\prime}$, are redefined by replacing σ_d^2 and σ_d^{*2} by σ_h^2 and σ_h^{*2}, respectively. Note that in the absence of direct income interactions, $\sigma_{hh}^* = 0$, and the above expressions reduce to the corresponding expressions in tables 1 and 2 under the same symmetry assumptions.

It is straightforward to establish that Proposition 1(a) still holds. Under flexible exchange rates, B_m^ε depends on σ_m^2 through the denominator Ω in (23), which in turn is a positive function of σ_m^2. Proposition 1(b), however, needs to be modified because with direct income interactions, flexible exchange rates do not insulate the response of the exchange rate to domestic money shocks from confusion about foreign disturbances. It can be established that the larger is σ_m^{*2} the *larger* is the absolute response of the real exchange rate to domestic money supply shocks.[16] Intuitively, an increase in σ_m^{*2} increases confusion about the foreign real demand shock entering the domestic goods and money market signals and hence about domestic money shock. The relative role of σ_m^2 as a source of confusion about real shocks is correspondingly reduced.

[16]In establishing this result and those below, we assume that $\sigma_h^2 > \sigma_{hh}^*$ and $\sigma_h^{*2} > \sigma_{hh}^*$.

In the fixed rate case, $B_m^{e'}$ depends on σ_m^2 and σ_m^{*2} through the denominator Ω' alone. Since Ω' is a positive function of σ_m^2 and σ_m^{*2}, it follows that Proposition 2(b) is unchanged: the absolute response of the real exchange rate to an unanticipated local-domestic (local-foreign) money supply shock is decreasing in the variance of both domestic and foreign money supply shocks.

Finally, we consider Propositions 2(a) and 2(c) which assert that the sensitivity of the coefficient of real exchange rate adjustment to domestic money shocks is less under fixed rates and the effect of increasing domestic (or foreign) money variance is smaller under fixed than under flexible exchange rates. While not immediately obvious, it can be shown that these results do indeed generalize under the assumptions made above of symmetry and shifts in real domestic demand having a stronger impact on the demand for domestic goods than on demand for foreign goods (i.e. b_3 and $b_3^* < 1$).

Another possible extension of the model is to relax the assumption of flexible prices in the determination of aggregate output. Many models attribute the real effects of monetary disturbances to wage or price rigidity. To the extent that the price rigidity embedded in contracts is based on relative confusion about underlying disturbances, the degree of this price rigidity may itself be a function of the relative variances of monetary and real disturbances along the lines of our analysis.

Allowing for international capital immobility would create additional channels through which monetary policy could have real effects. With such an extension, an additional source of disturbances – relative bond supplies – and an additional signal – the interest differential – would exist under both fixed and flexible exchange rates.

Another direction in which the analysis could be extended would be to introduce heterogeneous information sets among agents, as in Flood and Hodrick (1985a), or by endogenizing the information set, as in Glick and Wihlborg (1986).

6. Conclusions

In this paper we compare the real exchange rate effects of monetary (as well as real) disturbances under fixed and flexible nominal exchange rate regimes. Under reasonable conditions, the real exchange rate (and output) effects of monetary disturbances are larger under a flexible than under a fixed rate regime. The effects of increasing domestic money variance on real exchange rate adjustment are less with fixed than with flexible rates. Under a fixed exchange rate regime, without full or partial insulation of domestic money markets from confusion about foreign disturbances, shocks are more diversified and local money shocks are less likely to be attributed to real shocks.

Following Kimbrough (1984), we argue that a fixed exchange rate regime is less 'informative' than a flexible rate regime in the sense that the variance of the real exchange rate (and output) attributable to all unanticipated shocks is larger under a fixed regime. Nevertheless, the conditional variance attributable to monetary shocks is smaller with fixed rates under reasonable assumptions. It is because the conditional variance of the real exchange rate attributable to real shocks is larger with fixed rates that a fixed rate regime is less informative over all. Consequently, a fixed rate regime is relatively less informationally inferior as the relative variance of money increases.

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