

Eaton, Jonathan; Turnovsky, Stephen J.

**Working Paper**

## Effects of Monetary Disturbances on Exchange Rates with Risk Averse Speculation

Center Discussion Paper, No. 386

**Provided in Cooperation with:**

Yale University, Economic Growth Center (EGC)

*Suggested Citation:* Eaton, Jonathan; Turnovsky, Stephen J. (1981) : Effects of Monetary Disturbances on Exchange Rates with Risk Averse Speculation, Center Discussion Paper, No. 386, Yale University, Economic Growth Center, New Haven, CT

This Version is available at:

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ECONOMIC GROWTH CENTER

YALE UNIVERSITY

Box 1987, Yale Station  
New Haven, Connecticut

CENTER DISCUSSION PAPER NO. 386

EFFECTS OF MONETARY DISTURBANCES ON EXCHANGE  
RATES WITH RISK AVERSE SPECULATION

Jonathan Eaton and Stephen J. Turnovsky\*

September 1981

Notes: \* Australian National University and University of Illinois

This paper was prepared for presentation at the Warwick Summer Institute Workshop on International Macroeconomics, July, 1981.

Center Discussion Papers are preliminary materials circulated to stimulate discussion and critical comment. References in publications to Discussion Papers should be cleared with the author to protect the tentative character of these papers.

## 1. INTRODUCTION

With the general increase in exchange rate flexibility, the analysis of the determination of exchange rates has become a major area of research. An important aspect of the modelling of this process is the degree of capital mobility, with the polar assumption of perfect mobility being most widely adopted. This assumption, which is justified in terms of the observed mobility among the major currencies of the world, is usually specified in terms of uncovered interest parity, meaning that speculation brings the forward exchange rate in line with expectations of the future spot rate; see e.g. Argy and Porter (1972), Bilson (1978). Furthermore, the recent literature on rational expectations and exchange rate dynamics, in particular, has been built on this assumption; see e.g. Dornbusch (1976), Gray and Turnovsky (1979), Wilson (1979), Turnovsky and Kingston (1977), Flood (1979).

However, as several authors have shown, even if domestic and foreign bonds are perfect substitutes on a covered basis, the assumption of uncovered interest parity follows only if one adds the strong assumption that investors are risk neutral. If, more reasonably, investors are taken to be risk averse, the forward rate is not in general an unbiased predictor of the spot rate expected to prevail when the forward contract matures. The bias depends upon, among other things, asset supplies, the variability of exchange rates, and the degree of risk aversion; see e.g. Solnik (1973), Grauer, Litzenberger, and Stehle (1976), Kouri (1976), Adler and Dumas (1977), Roll and Solnik (1977), Eaton (1978), Frankel (1979), Fama and Farber (1979), Stein (1980). Furthermore, the theoretical existence of this bias is generally supported by available empirical evidence; see Levich (1978, 1979), Hansen and Hodrick (1980).

The relationship between the forward and expected future spot rates is crucial in determining the domestic interest rate, and hence in determining the current spot rate, the domestic price level, and domestic income. It is therefore important to analyze the determination of the exchange rate under

the more general assumption of risk averse speculative behavior.<sup>1</sup>

The present paper therefore has two objectives. The first is to develop a stochastic model of exchange rate determination which allows for risk averse speculative behavior. Secondly, we shall analyze the effects of a variety of disturbances consisting of: (i) changes in the supplies of money and bonds, (ii) forward market intervention, (iii) certain relevant foreign variables. In particular, we shall contrast the effects of transitory and permanent changes in these variables on the domestic economy and show how an increase in the elasticity of speculation with respect to the forward premium (reflecting a reduction in the degree of risk aversion) may influence the effects of the two types of disturbances in opposite ways. For example, we shall show that an increase in the degree of speculation is likely to *reduce* the expansionary effects of a *transitory* monetary disturbance, on the one hand, but to *increase* the expansionary effects of a *permanent* monetary disturbance, on the other. This result can also be looked at another way. It means that if in fact investors are risk averse, then the prevalent procedure of equating the forward rate to the expected future spot rate (and hence assuming risk neutrality) may *understate* the effects on income and the spot rate of temporary changes in the money supply and necessarily overstates the corresponding effects of *permanent* changes.

We shall also show that less risk-averse speculation increases the sensitivity of income to announcements of *future* changes in money supply. As speculators become less risk averse, forward intervention policy and changes in the domestic supply of bonds have less effect on income and exchange rates regardless of whether these policies are temporary or permanent. Domestic income becomes more sensitive to changes in foreign variables, however, as speculation becomes more risk neutral.

The remainder of the paper proceeds as follows. Section 2 outlines the model underlying our analysis, with the solution being provided in Section 3. Sections 4 through 6 discuss the effects of changes in the money supply, bond supply and forward market intervention, and foreign variables, respectively

Some concluding remarks are provided in Section 7.

## 2. THE FORWARD EXCHANGE MARKET IN A SIMPLE MACRO MODEL

The model we shall consider is kept as simple as possible to enable us to focus on the main issues without undue complication. Specifically, we shall assume that there is a single traded commodity, whose price in terms of foreign currency is given. Also, we shall assume that the domestic bond is a perfect substitute for a traded world bond when fully covered against exchange risk. Thus purchasing power parity (PPP) and covered interest parity (CIP) are assumed to hold:

$$p_t = e_t^s + p_t^* \quad (1)$$

$$i_t = i_t^* + e_t^f - e_t^s \quad (2)$$

where  $p_t$  = domestic price of the traded good at time  $t$ , expressed in logarithms,

$p_t^*$  = foreign price of the traded good at time  $t$ , expressed in logarithms,

$e_t^s$  = current *spot* exchange rate (measured in units of domestic currency per unit of foreign currency), expressed in logarithms,

$e_t^f$  = forward exchange rate at time  $t$  for delivery at time  $t+1$  (measured in terms of units of domestic currency per unit of foreign currency), expressed in logarithms,

$i_t$  = domestic nominal interest rate at time  $t$ ,

$i_t^*$  = foreign nominal interest rate at time  $t$ .

The domestic economy is assumed to be small so that  $p_t^*$ ,  $i_t^*$  are exogenous; foreign bonds and goods are supplied perfectly elastically at the world interest rate  $i_t^*$  and foreign price level  $p_t^*$ , respectively.

Domestic money market equilibrium is described by the relationship

$$m_t - p_t = \alpha_1 y_t - \alpha_2 i_t \quad (3)$$

where  $m_t$  = domestic nominal money supply, expressed in logarithms,

$y_t$  = domestic real output at time  $t$ , expressed in logarithms.

This specification is of the usual form. In particular, we make the conventional assumption that all domestic money is held by domestic residents, who in turn hold no foreign money.

The specification of the forward market requires somewhat more discussion. Private participation in the forward market may take place for two reasons, speculation or arbitrage.<sup>2</sup> The net *supply* of foreign exchange forward for *arbitrage* purposes in real terms equals the net real holdings of foreign bonds by the domestic, private sector. Forward market equilibrium requires that this quantity equal the net *speculative demand* for foreign exchange forward plus net government purchases of foreign exchange forward both in real terms. The condition for forward market equilibrium at time  $t$  is therefore

$$\frac{E_t D_t^F}{P_t} = \frac{D_t^F}{P_t^*} = S_t + \frac{G_t}{P_t^*}. \quad (4)$$

Here  $E_t$ ,  $P_t$  and  $P_t^*$  denote the exchange rate, the domestic price level and the foreign price level, all measured in natural units.  $D_t^F$  is the nominal stock of foreign bonds (denominated in foreign currency) held by domestic residents;  $S_t$  is the real speculative demand for foreign exchange forward and  $G_t$  is net nominal holdings by the government of foreign exchange forward. (The first part of (4) follows from the purchasing power parity condition  $P_t = E_t P_t^*$ ).

Following the theoretical literature, we assume that the real supply of foreign exchange for speculation is a function of the expected rate of return on the forward purchase of foreign currency. We approximate this relationship by the expression<sup>3</sup>

$$S_t = \gamma(e_{t+1,t}^s - e_t^f) \quad (5)$$

where  $e_{t+1,t}^s$  denotes the expectation of the spot for time  $t+1$ , as of time

t. The parameter  $\gamma$  is a decreasing function of the degree of relative risk aversion. As the degree of relative risk aversion tends to zero, so that risk neutrality is approached,  $\gamma \rightarrow \infty$ , implying  $e_{t+1,t}^s = e_t^f$ ; i.e., the forward rate becomes an unbiased predictor of the spot rate.

Since, by assumption, covered foreign bonds are perfect substitutes for domestic bonds, the real demand for foreign bonds is simply the real demand for *all* bonds,  $D_t$ , less the real supply of domestic bonds  $B_t/P_t$ , where  $B_t$  is the nominal stock of domestic bonds denominated in domestic currency; i.e.,

$$\frac{D_t^F}{P_t^*} = D_t - \frac{B_t}{P_t} \quad (6)$$

The total real demand for bonds  $D_t$  is specified by the relationship

$$D_t = \omega_1 y_t + \omega_2 i_t \quad \omega_2 > 0 \quad (7)$$

While it is reasonable to assume that  $D_t$  is an increasing function of the domestic interest rate, the response of  $D_t$  to income is much more indeterminate and therefore we place no sign restriction on  $\omega_1$ . The presence of the term  $B_t/P_t$  in (6) causes the demand for foreign bonds to remain non-linear. Denoting  $\ln B_t$  by  $b_t$  a linear approximation to  $D_t^F/P_t^*$  is given by<sup>4</sup>

$$D_t^F/P_t^* = D_t - \omega_4 - \omega_3(b_t - p_t) \quad (8)$$

where  $\omega_3 \approx (\bar{B}_t/\bar{P}_t)$ , the average stock of domestic bonds divided by the average price level and  $\omega_4 \approx \omega_3[1 - \ln \omega_3]$ . We shall normalize units so that  $\ln \omega_3 = 1$  and  $\omega_4 = 0$ , in which case substituting (7) into (8) we obtain

$$D_t^F/P_t^* = \omega_1 y_t + \omega_2 i_t - \omega_3(b_t - p_t). \quad (8')$$

Likewise, the real government intervention  $G_t/P_t^*$  is also non-linear and by a similar process a linear approximation is given by<sup>5</sup>

$$G_t/P_t^* = \lambda(g_t - p_t) \quad (9)$$

where  $\lambda \approx (\bar{G}_t/\bar{P}_t^*)$ , the average real stock of forward exchange held by the government, and  $g_t \equiv \ln G_t$ . Units are chosen so that  $\ln \lambda = 1$ .

Substituting equations (5), (8'), (9) into (4), we obtain the following condition for forward market equilibrium:

$$\omega_1 y_t + \omega_2 i_t - \omega_3 (b_t - p_t) = \gamma (e_{t+1,t}^s - e_t^f) + \lambda (g_t - p_t^*). \quad (10)$$

Finally, we assume that deviations in output from its natural level  $\bar{y}$  are determined by the unanticipated component of the domestic price level.

That is,

$$y_t = \theta (p_t - p_{t,t-1}) \quad (11)$$

where we normalize units by setting  $\bar{y} = 0$ , and  $p_{t,t-1}$  denotes the expectation of the price level for time  $t$  formed at time  $t-1$ . Such a specification follows from the contract theory of wage determination of Gray (1976), Fischer (1977) and Phelps and Taylor (1977).

This completes the specification of the model. Together, equations (1), (2), (3), (9) and (10) determine the equilibrium values of the five endogenous variables  $p_t$ ,  $i_t$ ,  $e_t^s$ ,  $e_t^f$  and  $y_t$  in terms of the expectations  $e_{t+1,t}^s$ ,  $p_{t,t-1}$  and the exogenous variables  $i_t^*$ ,  $p_t^*$ ,  $m_t$ ,  $b_t$ ,  $g_t$ , as well as the structural parameters of the system. The only thing that remains before solving the model is the description of expectations, which we take to be formed rationally; i.e. price and exchange rate expectations are optimally generated forecasts based on a solution of the model itself using all available information.

### 3. DETERMINATION OF SOLUTION

Substituting equations (1), (2) and (11) into equations (3) and (10) we obtain two equations, one a condition for money market equilibrium, the other a condition for forward market equilibrium. Together these equations determine the spot and forward rates of exchange. In matrix form, the two equilibrium equations are

$$\begin{bmatrix} 1 + \alpha_1 \theta + \alpha_2 & -\alpha_2 \\ \omega_2 - \omega_1 \theta - \omega_3 & -\omega_2 - \gamma \end{bmatrix} \begin{bmatrix} e_t^s \\ e_t^f \end{bmatrix} = \begin{bmatrix} v_t^m \\ v_t^f \end{bmatrix} \quad (12)$$



where  $v_t^m \equiv m_t - (1 + \alpha_1 \theta) p_t^* + \alpha_2 i_t^* + \alpha_1 \theta p_{t,t-1}$

$$v_t^f \equiv -\omega_3 b_t - \lambda g_t + (\omega_1 \theta + \omega_3 + \lambda) p_t^* + \omega_2 i_t^* - \omega_1 \theta p_{t,t-1} - \gamma e_{t+1,t}^s.$$

Given current expectations about the future and past expectations about the present, the first line of (12) determines a relationship between  $e_t^s$  and  $e_t^f$  that equilibrates the money market and which we label the MM curve. It appears in Figure 1 and has the slope  $(1 + \alpha_1 \theta + \alpha_2)/\alpha_2 > 1$ . The second line of (12) determines a relationship between  $e_t^s$  and  $e_t^f$  that equilibrates the forward exchange market and which we label the FF curve. It has slope  $(\omega_2 - \omega_1 \theta - \omega_3)/(\omega_2 + \gamma)$  which can be of either sign. We shall assume, however, that it is less steep than the MM curve. This will certainly be so if the income elasticity of the demand for bonds,  $\omega_1$ , is not strongly negative.

The ambiguity in the slope of the FF curve arises for the following reason: An increase in  $e_t^s$  causes  $p_t$  to rise, reducing the real supply of domestic bonds. This raises the demand for foreign bonds and hence the supply of foreign exchange forward. To generate an offsetting speculative demand for foreign exchange forward requires a lower value of  $e_t^f$ . However, an increase in  $e_t^s$  also lowers  $i_t$  and hence the demand for bonds. This has the opposite effect on  $e_t^f$ . The first effect dominates where domestic bonds are a large share of total bond holdings and the demand for bonds is relatively interest-inelastic ( $\omega_3 > \omega_2$ ). Conversely, the second effect dominates when  $\omega_2 > \omega_3$ .

For the case in which speculators are risk neutral ( $\gamma \rightarrow \infty$ ) the FF curve becomes horizontal. The forward rate is determined solely in the forward market by speculative behavior, which ensures that  $e_t^f = e_{t+1,t}^s$ . When the demand for money is interest inelastic,  $\alpha_2 = 0$ , and the MM curve becomes vertical. The spot rate is determined solely by money market

equilibrium. Otherwise, equilibrium values of the two rates are determined simultaneously in the two markets.

In drawing the MM and FF curves, the expectations  $e_{t+1,t}^S$ ,  $p_{t,t-1}$  have been taken as given. We now endogenize these variables by solving for the rational expectations equilibrium of the model.

To do so, we first solve (12) (recalling (1), (11)) to obtain

$$e_t^S = u_t^S + \phi_{t+1,t}^S - \rho \Delta^{-1} y_t \quad (13)$$

where  $u_t^S \equiv [(\omega_2 + \gamma)m_t + \alpha_2 \omega_3 b_t + \alpha_2 \lambda g_t - [\omega_2 + \gamma + \alpha_2(\omega_3 + \lambda)]p_t + \alpha_2 \gamma i_t^*] \Delta^{-1}$

$$\Delta \equiv (\omega_2 + \gamma) + \alpha_2(\gamma + \omega_3)$$

$$\phi \equiv \alpha_2 \gamma \Delta^{-1} < 1$$

$$\rho \equiv \alpha_1(\omega_2 + \gamma) + \alpha_2 \omega_1$$

Now take expectations from some arbitrary initial period  $0 < t$ . Using the property of rational expectations that  $E(e_{t+1,t}^S | \Omega) = e_{t+1,0}^S$ , where  $\Omega_0$  denotes information available at time 0, and taking conditional expectations of (11) to show  $y_{t,\tau} = 0$ ,  $\tau < t$ , we obtain

$$e_{t,0}^S = u_{t,0}^S + \phi e_{t+1,0}^S \quad (14)$$

To solve (14) we shall adopt the method of undetermined coefficients, hypothesizing a solution of the form

$$e_{t,0}^S = \sum_{i=0}^{\infty} \mu_i u_{t+i,0}^S + k_t \quad (15)$$

Substituting (15) into (14), we obtain

$$\left( \sum_{i=0}^{\infty} \mu_i u_{t+i,0}^S + k_t \right) = u_{t,0}^S + \phi \left( \sum_{i=1}^{\infty} \mu_{i-1} u_{t+i,0}^S + k_{t+1} \right) \quad (16)$$

and equating coefficients, we find

$$k_t = \phi k_{t+1} \quad (17a)$$

$$\mu_i = \phi \mu_{i-1} \quad (17b)$$

$$\mu_0 = 1. \quad (17c)$$

The general solution to (14) is thus of the form

$$e_{t,0}^s = \sum_{i=0}^{\infty} \phi^i u_{t+i,0}^s + k_0 \phi^{-i} \quad (18)$$

where  $k_0$  is an arbitrary constant. Since  $\phi < 1$ , to ensure that  $e_{t,0}^s$  remains bounded as  $t \rightarrow \infty$ , we impose the restriction that  $k_0 = 0$ .<sup>6</sup>

Thus from (18) it follows that

$$e_{t+1,t}^s = \sum_{i=0}^{\infty} \phi^i u_{t+i+1,t}^s \quad (19)$$

while the solution for the actual spot rate,  $e_t^s$ , is obtained by substituting (19) into (13), recalling that  $u_{t,t}^s = u_t^s$ . Thus we obtain

$$e_t^s = \sum_{i=0}^{\infty} \phi^i u_{t+i,t}^s - \rho \Delta^{-1} y_t. \quad (20)$$

To solve for current output  $y_t$ , we substitute the purchasing power relationship (1) into the supply function (11). Using (19) at time  $t-1$ , together with (20), we may write the solution for  $y_t$  in the form

$$y_t = \frac{\theta \Delta}{\Delta + \rho \theta} \left\{ (u_t^s - u_{t,t-1}^s) + \sum_{i=1}^{\infty} \phi^i (u_{t+i,t}^s - u_{t+i,t-1}^s) + p_t^* - p_{t,t-1}^* \right\}. \quad (21)$$

From (21) we observe that  $y_t$  depends upon the unanticipated components of changes in the foreign price level ( $p_t^* - p_{t,t-1}^*$ ) and the composite disturbance term ( $u_t^s - u_{t,t-1}^s$ ). In addition, it depends upon an infinite discounted sum of terms ( $u_{t+i,t}^s - u_{t+i,t-1}^s$ ), which measure the extent to which forecasts of  $u_{t+i}^s$  are updated between periods  $t-1$  and  $t$ , as information at time  $t$  becomes available.

An expression for  $e_t^f$  can be obtained by solving (12) and substituting (19), yielding

$$e_t^f = u_t^f + (1+\alpha_2)\gamma\Delta^{-1} \sum_{i=0}^{\infty} \phi^i u_{t+i+1,t}^s + [\alpha_1(\omega_2 - \omega_3) - (1+\alpha_2)\omega_2]\Delta^{-1} y_t \quad (22)$$

where

$$u_t^f \equiv [\omega_2 - \omega_3]m_t + (1 + \alpha_2)\omega_3 b_t + \lambda(1 + \alpha_2)(g_t - p_t^*) - (\omega_2 + \alpha_2\omega_3)(i_t^* + p_t^*)] \Delta^{-1}.$$

Through the terms  $e_{t+i,t}^s$ , the current values of income and the spot and forward exchange rates depend upon the entire time profile of expectations of all future money supplies, bond supplies, government position in the forward market, and relevant foreign disturbances. Equations (20), (21), (22) form the basis for our subsequent analysis. Reduced form expressions for  $e_t^s$  and  $e_t^f$  may be obtained by substituting the solution for  $y_t$ , (21), into (20), (22), but it is not necessary to report these explicitly. In subsequent sections below we consider the effects of three types of disturbances on the economy:

- (i) various forms of domestic monetary expansion;
- (ii) various forms of bond market or forward market intervention by the domestic monetary authorities;
- (iii) international disturbances, taking the form of changes in the foreign price level and foreign interest rate.

These three topics are addressed in Sections 4-6 respectively.

#### 4. DOMESTIC MONETARY EXPANSION

From the solution (20) - (22) the effects of an infinite range of monetary disturbances can in principle be analyzed. These disturbances can most usefully be distinguished in terms of: (a) the extent to which they are anticipated or unanticipated; (b) their expected permanence or transience; (c) whether they occur immediately or are announced. Any specific monetary disturbance can be parameterized quite explicitly by imposing the appropriate changes on the relevant terms appearing in the expressions  $u_{t+i,t}^s$ ,  $u_{t+i,t}^f$ . Obviously we can discuss just a limited number of disturbances, although others can be considered along similar lines. In all cases, the monetary disturbance will take the form of an increase in the money supply  $dm_t$ , which is effected by a transfer. An open market operation can, however, be readily treated in a similar way; see footnote 8 below.

#### 4.1 An Unanticipated, Temporary Increase in the Money Supply

The initial disturbance in the money supply we shall consider is one which is: (i) unanticipated as of period  $t-1$ , and (ii) expected to last only during period  $t$ . It is therefore a purely random one-period shock. Accordingly,  $du_{t+i,t}^S = du_{t+i,t-1}^S = 0$ ,  $i \neq 0$ .

This disturbance can be treated quite conveniently by means of the MM and FF curves given in Figure 1. Since  $u_{t+i,t}^S$  remains fixed, the spot rate expected to prevail in period  $t+1$  and given by the expression (19) is also unaffected by the changes being considered; that is,  $de_{t+1,t}^S = 0$ . Thus the assumption of constant expectations incorporated in the MM and FF curves is consistent with rational expectations when disturbances in the money supply are perceived as temporary.

The effect of a random transfer in the money supply  $dm$  is to shift the MM curve rightward. At any given forward rate, a higher spot rate is required to restore money market equilibrium. The FF curve is unaffected by the change. Since, by assumption, the MM curve is steeper than the FF curve, the spot rate rises, as does the forward rate if FF is upward sloping. In terms of Figure 1, the equilibrium moves from A to B, say. As long as the slope of the FF curve is less than one (which will be the case unless  $\omega_3$  is highly negative),  $e_t^S$  rises by more than  $e_t^F$  and the domestic interest rate falls. Thus a temporary increase in the money supply is reflected more in the current spot rate than it is in the forward rate. Given that we would expect the spot rate to be more sensitive to current random disturbances, while forward rates will tend to reflect more permanent changes, this result makes good intuitive sense.

The effect of an increase in  $m_t$  on income  $y_t$  is given by

$$\left( \frac{dy_t}{dm_t} \right)_{tr} = \frac{\theta(\omega_2 + \gamma)}{\Delta + \rho\theta} \quad (23)$$

where the subscript  $tr$  refers to "transitory". Thus an unanticipated increase in the money supply that is not expected to persist has an expansionary effect. Differentiating (23) with respect to  $\gamma$  reveals that an increase in

the elasticity of speculation has an ambiguous effect on the size of the income response. If the FF curve slopes up more elastic speculation diminishes the effect, and conversely. The same comments apply to the effects of increased speculation on the spot rate.

An increase in  $\gamma$  ties the forward rate more closely to the expected future spot rate: whatever its slope, the FF curve becomes more horizontal. When the FF curve slopes up an increase in the money supply raises the forward rate and conversely. Increased speculation reduces the absolute magnitude of the response. If the forward rate *rises* as a result of the monetary expansion, increased speculation reduces the extent of this rise. The fall in the forward premium and hence in the domestic interest rate (via the interest rate parity condition (2)) is increased, thereby increasing the expansionary effect on income. Conversely, if the forward rate *falls* as a result of the monetary expansion then more speculation reduces the extent of this fall. The fall in the interest rate is reduced, as is the expansionary effect on income.

#### 4.2 The Effects of Changes in Expectations

Any change in the money supply that is expected to be permanent also has effects on expectations. In order to consider these we analyze the effects of an increase in  $e_{t+1,t}^s$  on  $e_t^s$  and  $e_t^f$ .

An increase in  $e_{t+1,t}^s$  shifts the FF curve upward by an amount  $\gamma/(\omega_2 + \gamma)$ , leaving the MM curve unchanged, thereby shifting the equilibrium from A to C in Figure 1. Both the spot and forward rates rise, the forward rate by proportionately more. As the elasticity of speculation increases, so does the response of both rates to changes in expectations, with the increased responsiveness of the spot rate increasing that of income.

#### 4.3 The Effects of an Unanticipated, Permanent Change

We now consider the effects of a monetary expansion that initially is unanticipated, but having occurred is expected to be permanent. This form of monetary disturbance has recently been discussed extensively in the literature, and has shown to give rise to the possibility of "overshooting" of the spot exchange rate to a monetary disturbance; see Dornbusch (1976), Turnovsky (1981).

Any monetary expansion that is expected to be permanent influences the system in two ways. It operates first through the channels discussed in Section 4.1 and second, through its effects on expectations noted in Section 4.2. These changes are illustrated in Fig. 1 as a change from A to D. In the extreme case in which speculators are infinitely risk averse ( $\gamma = 0$ ), expectations have no effect on the present and it is therefore irrelevant whether a particular change is perceived as permanent or temporary. Otherwise, both channels must be considered.

The impact effect of an unanticipated change in the money supply that *ex post* is expected to be permanent is given by

$$\left( \frac{dy_t}{dm_t} \right)_p = \frac{\theta(\omega_2 + \gamma)}{(1-\phi)(\Delta + \rho\theta)} \quad (24)$$

where the subscript  $p$  refers to "permanent". Comparing (24) with (23), we see that the response of income is larger when the change in the money supply is perceived as being permanent. In this case  $e_{t+1,t}^s$  becomes greater, thereby reinforcing the expansionary effect resulting from the increased money supply.

The effects on the spot and forward rates are given by

$$\left( \frac{de_t^s}{dm_t} \right)_p = \frac{\omega_2 + \gamma}{(1-\phi)(\Delta + \rho\theta)} \quad (25a)$$

$$\left( \frac{de_t^f}{dm_t} \right)_p = \frac{\omega_2 - \theta\omega_1 - \omega_3 + (1+\rho\theta/\Delta)\gamma}{(1-\phi)(\Delta + \rho\theta)} \quad (25b)$$

From (25a) it is seen that a 1% increase in the money supply leads to a less than 1% devaluation of the spot rate. Provided that the FF curve is upward sloping the monetary expansion will increase the forward rate, although again less than proportionately. The ratio of the effects of a permanent increase in the money supply upon the forward and spot rates is given by the expression

$$\frac{\omega_2 - \theta\omega_1 - \omega_3 + (1+\rho\theta/\Delta)\gamma}{\omega_2 + \gamma} \quad (26)$$

while the corresponding ratio with respect to temporary disturbances is

$$\frac{\omega_2 - \theta\omega_1 - \omega_3}{\omega_2 + \gamma} \quad (27)$$

Comparing these two ratios we may infer that unless  $\omega_1$  is very negative, an increase in the money supply will have a relatively greater effect on the forward rate when it is expected to be permanent than when it is expected to be transitory. This result makes perfectly good intuitive sense for the reasons noted in Section 4.1.

An increase in the elasticity of speculation *increases* the extent to which income and the two exchange rates respond to a permanent increase in the money supply. This result contrasts with the ambiguous effects of increasingly elastic speculation on the response to a temporary increase. Since elastic speculation ties the current spot rate and income more closely to the future, it may dampen the effects of temporary changes, but it amplifies the effects of permanent ones. As the elasticity of speculation tends to infinity, we obtain

$$\left( \frac{de_t^s}{dm_t} \right)_p = \frac{1+\alpha_2}{1+\alpha_1\theta+\alpha_2} < 1 \quad (28a)$$

$$\left( \frac{de_t^f}{dm_t} \right)_p = 1 \quad (28b)$$

Thus far we have considered only the *impact* effects of a permanent change in the money supply. These short-run responses in the exchange rates  $e_t^s, e_t^f$  include an income effect, which operates through the last term in equations (20), (22). For  $\tau > t$ , income reverts to its steady state level of zero. The *permanent* changes in the spot and forward rates are respectively,

$$\left( \frac{de_\tau^s}{dm_t} \right)_p = \frac{\omega_2 + \gamma}{\omega_2 + \gamma + \alpha_2 \omega_3} \quad \tau > t \quad (29a)$$



$$\left( \frac{de_t^f}{dm_t} \right)_p = \frac{\omega_2 - \omega_3 + \gamma}{\omega_2 + \gamma + \alpha_2 \omega_3} \quad \tau > t \quad (29b)$$

When  $\omega_3 > 0$  and  $\alpha_2 > 0$  the permanent change in the spot rate is less than the permanent change in the money supply while the permanent change in the forward rate is even lower. The reason is that the initial increase in the price level reduces the real supply of bonds, increasing the demand for foreign bonds, and lowering  $e_t^f$ . The consequent decline in the domestic interest rate raises the demand for money, so that a proportional change in the price level is not required.

Comparing (29a) and (25a) we see that the steady state response of the spot exchange rate to an unanticipated permanent increase in the money supply exceeds its response on impact. That is, the exchange rate "undershoots" its long-run response. While this result is in contrast the overshooting obtained by Dornbusch, the difference is due to differences in assumptions and accords with similar results in the literature. The critical factors in our model are: (i) that the domestic price level is not only flexible, but also tied to the world price via PPP; (ii) the endogeneity of income. As a consequence, any nominal expansion in the money supply is accommodated partly by income changes and partly by price changes, thereby requiring less adjustment in the exchange rate.<sup>7</sup>

#### 4.4 Announcement Effects

Thus far we have considered temporary and permanent increases in the money supply that were unanticipated as of the period before which they actually occurred. If, instead, we consider changes in period  $t$  that are announced in period  $t-k$ , our analysis is subject to several modifications.

First, there are real effects only during period  $t-k$ , when the announcement is made. In all subsequent periods prices are correctly anticipated. The effects of *one-period* changes in period  $t$ , the time the policy is put into effect, on  $e_t^s$  and  $e_t^f$  can be obtained as before, only with the income effects removed. Algebraically, these results may be obtained by replacing  $\theta$  with 0 in the analysis in Section 4.1. No qualitative

differences in the responses of  $e_t^s$  and  $e_t^f$  arise when temporary changes are anticipated. When *permanent* changes are anticipated,  $e_t^s$  and  $e_t^f$  assume their new *steady-state* values, as income effects are now absent.

Exchange rates from periods  $t-k$  until  $t$  are affected solely by the effect of the announcement on expectations. Having computed the effect on  $e_t^s$ , the effects on  $e_{t-1}^s$  and  $e_{t-1}^f$  may be derived via the analysis in Section 4.2, again with the income effects suppressed (unless  $k = 1$ ). The effects on  $e_{t-i}^s$   $k > i > 1$  may be solved similarly via backward iteration. In period  $t-k$ , the announcement period, the income effect is no longer suppressed.

The effect of the announcement monetary increase on income during the announcement period,  $y_{t-1}$ , is given by the expression

$$\frac{dy_{t-k}}{dm_t} = \frac{\theta(\alpha_2 \gamma \Delta^{-1})^k}{\Delta + \rho \theta} \frac{de_t^s}{dm_t}.$$

Thus the effect on  $y_{t-k}$  is qualitatively independent of the lag, but declines quantitatively as the lag becomes longer and speculation and money demand becomes less elastic. In particular, if the demand for money is interest inelastic or speculation inelastic, changes announced in advance have no effects on real activity at any stage. Thus less risk-averse speculation raises the sensitivity of income to preannounced monetary changes.

## 5. FORWARD MARKET INTERVENTION AND CHANGES IN DOMESTIC BOND SUPPLY

The effects of forward market intervention by the domestic government and changes in the supply of domestic bonds can be described by considering various changes in  $g_t$  and  $b_t$ . Note that  $g_t$  and  $b_t$  appear in (12) additively. Thus changes in these policy variables have parallel effects. An increase in  $b_t$  reduces the demand for foreign bonds and hence the supply of foreign exchange forward for arbitrage. The private speculative demand for foreign exchange forward required to equilibrate the forward market is thereby reduced. A government purchase of foreign exchange forward does the same thing directly. In either case a higher value of  $e_t^f$  is compatible with

forward market equilibrium. As with a monetary disturbance, these two changes can take various forms (anticipated versus unanticipated, temporary versus permanent, etc.) and can be analyzed in a similar fashion to Section 4. For this reason our comments can be brief.

Consider the effects of an unanticipated, one-period increase in the supply of domestic bonds or, equivalently, a one-time central bank purchase of foreign exchange in the forward market. Either will bid up  $e_t^f$ , given any value of  $e_t^s$ : the FF curve in Figure 1 shifts up. Both spot and forward rates will therefore rise. Since the slope of the MM curve exceeds unity, the forward rate rises by more than the spot rate, so that the domestic interest rate rises. Since  $e_t^s$  rises, so does the domestic price level, and with it domestic output. Thus these effects are qualitatively similar to those of a temporary monetary expansion, except that direct intervention in the forward market has a relatively greater effect on the forward rate. Consequently expansion is accompanied by an increase rather than a decrease in the interest rate.

As the elasticity of speculation increases, the forward rate becomes increasingly tied to the expected future rate and the upward shift in the FF curve diminishes, reducing the overall impact of the intervention on the endogenous variables  $e_t^s$ ,  $e_t^f$ , and  $y_t$ . In the limit, as speculation becomes perfectly elastic, all these effects vanish.

Turning now to an unannounced increase in  $b_t$  that *ex post* is expected to be permanent or, equivalently, a central bank purchase of foreign exchange forward that is expected to be maintained each period, we may show that, as with a temporary change in  $g_t$  or  $b_t$ , the forward rate responds more than the spot rate. This is true both on impact and in steady state. Thus an increase in  $g_t$  or  $b_t$  will raise the domestic interest rate permanently, unless the elasticity  $\gamma$  is infinite, in which case all effects tend to zero.<sup>7</sup>

Finally, we note that steady state values of  $e^s$ ,  $e^f$ , and  $p$  are homogeneous of degree one in  $b$  and  $m$ , while  $i$  and  $y$  are homogeneous of degree zero. Hence permanent proportional increases in  $b$  and  $m$  have no effect on the covered interest differential,  $\Delta c$ .

## 6. INTERNATIONAL DISTURBANCES

The effects of disturbances in the two foreign variables  $p^*$  and  $i^*$  can be analyzed similarly. In general, these two variables will move simultaneously as they respond to common influences abroad. For example, an increase in demand abroad will cause both  $p^*$  and  $i^*$  to rise, while a monetary expansion abroad will cause  $i^*$  to fall but  $p^*$  to rise. For simplicity, we shall focus on the two disturbances separately, recognizing that any real world disturbance will be some composite of the two effects.

### 6.1 Foreign Price Level Disturbance

An unanticipated temporary increase in  $p_t^*$  will shift the MM curve to the left while the FF curve falls vertically, causing both  $e_t^s$  and  $e_t^f$  to fall. As speculation becomes more elastic the size of the shift in the FF curve diminishes and in the limit, as  $\gamma$  tends to infinity, the FF curve remains fixed. Thus as  $\gamma$  rises the effect of a foreign price increase on the exchange rate diminishes.

The effect of the foreign price disturbance on domestic income is

$$\left( \frac{dy_t}{dp_t^*} \right)_{tr} = \frac{\theta \alpha_2 (\gamma - \lambda)}{\Delta + \rho \theta} \quad (30)$$

Provided that the average of level intervention in the forward market is less than the elasticity of speculation ( $\lambda < \gamma$ ), an increase in the foreign price level generates a less than proportional fall in the spot rate so that the domestic price level rises, causing income to rise as well. The existence of a positive government position in the forward market ( $\lambda > 0$ ) causes  $e_t^s$  and  $e_t^f$  to fall further in response to an increase in  $p_t^*$ , providing an offsetting contractionary effect. Indeed, if the net government position is sufficiently large, income may actually fall. Only when  $\alpha_2 = 0$  or  $\gamma = \lambda$  is the response of the exchange rate proportional, so that income is unaffected. As speculation becomes more elastic, exchange rates become more under the influence of future expectations and respond less to current foreign price changes. The effect of a change in the foreign price level is

consequently more fully reflected in the domestic price level, so that the response of income is increased.

In the absence of a government net position in the forward exchange market, the effect of an unanticipated *permanent* change in  $p_t^*$  on  $y_t$  is zero. The spot rate appreciates by the amount of the foreign price increase. Thus there is no effect on the domestic price level. The forward rate also changes by the same amount. Therefore, even on impact, changes in the foreign price level that are perceived as permanent have no real effects. See Harris and Purvis (1979) for a similar result. With  $\lambda > 0$ , however, an unanticipated permanent increase in  $p_t^*$  generates a more than proportional appreciation of the spot rate, causing domestic income to fall.

## 6.2 Foreign Interest Rate Disturbance

An unanticipated one-period increase in  $i_t^*$  leads to downward shifts in both the MM and FF curves. The fall in the former exceeds that of the latter so that the spot rate rises, while the response of the forward rate is ambiguous. Because of the rise in the spot rate, the domestic price level and output also rise. As speculation becomes more elastic the shift of the FF curve declines in absolute magnitude and the increases in the spot rate and income become greater.

The effect of an unanticipated change in the foreign interest rate that is perceived as being *permanent* on income is

$$\left( \frac{dy_t}{di_t^*} \right)_p = \frac{\alpha_2 \gamma \theta}{(1-\phi)(\Delta + \rho \theta)} \quad (31)$$

with an increase in the elasticity of speculation increasing the magnitude of this impact. It is interesting to note that, in steady state, the change in the domestic interest rate resulting from a permanent change in the foreign rate is

$$\left( \frac{di_t}{di_t^*} \right)_p = 1 + \left( \frac{de_t^f}{di_t^*} \right)_p - \left( \frac{de_t^s}{di_t^*} \right)_p = \frac{\gamma}{\omega_1 + \gamma + \alpha_2 \omega_3} \quad (32)$$

In general a permanent rise in the foreign interest rate leads to a less than proportional rise in the domestic interest rate. If speculation is perfectly inelastic there is no effect, while as speculation becomes perfectly elastic, the effect tends toward exact proportionality.

## 7. CONCLUSIONS

This paper has developed a macroeconomic model in which domestic and foreign bonds are perfect substitutes on a covered basis, but in which speculators are assumed to be risk averse. Under such conditions, previous portfolio investment models have shown a risk premium on forward exchange is likely to be established. We have analyzed the effects of various transitory and permanent disturbances on the economy and shown how the existence of the risk premium has important implications for macroeconomic behavior.

Perhaps of greatest interest is the proposition that an increase in the degree of speculation, reflecting a reduction in the degree of risk aversion, is likely to reduce the expansionary effects of a transitory increase in the money supply, on the one hand, while increasing the expansionary effects of a permanent increase, on the other. From this it follows that the assumption of perfectly elastic speculation (under which the risk premium is eliminated) is likely to overstate the difference between permanent and temporary changes. This assumption also tends to exaggerate the announcement effects of changes to occur in the future.

Because our model explicitly incorporates a forward market, it suggests some interesting implications as to how spot and forward rates reveal information about expectations. Typically, changes that are perceived as being permanent are reflected relatively more in the forward rate, while the spot rate responds more to changes that are seen as being only temporary.

Our analysis has focused primarily on how the economy responds to temporary and permanent changes in the money and bond supplies and in the

central bank's forward market position. A natural extension of this is the design of money supply and forward market intervention rules that stabilize the domestic economy in the face of stochastic disturbances. This issue is taken up elsewhere.<sup>9</sup>

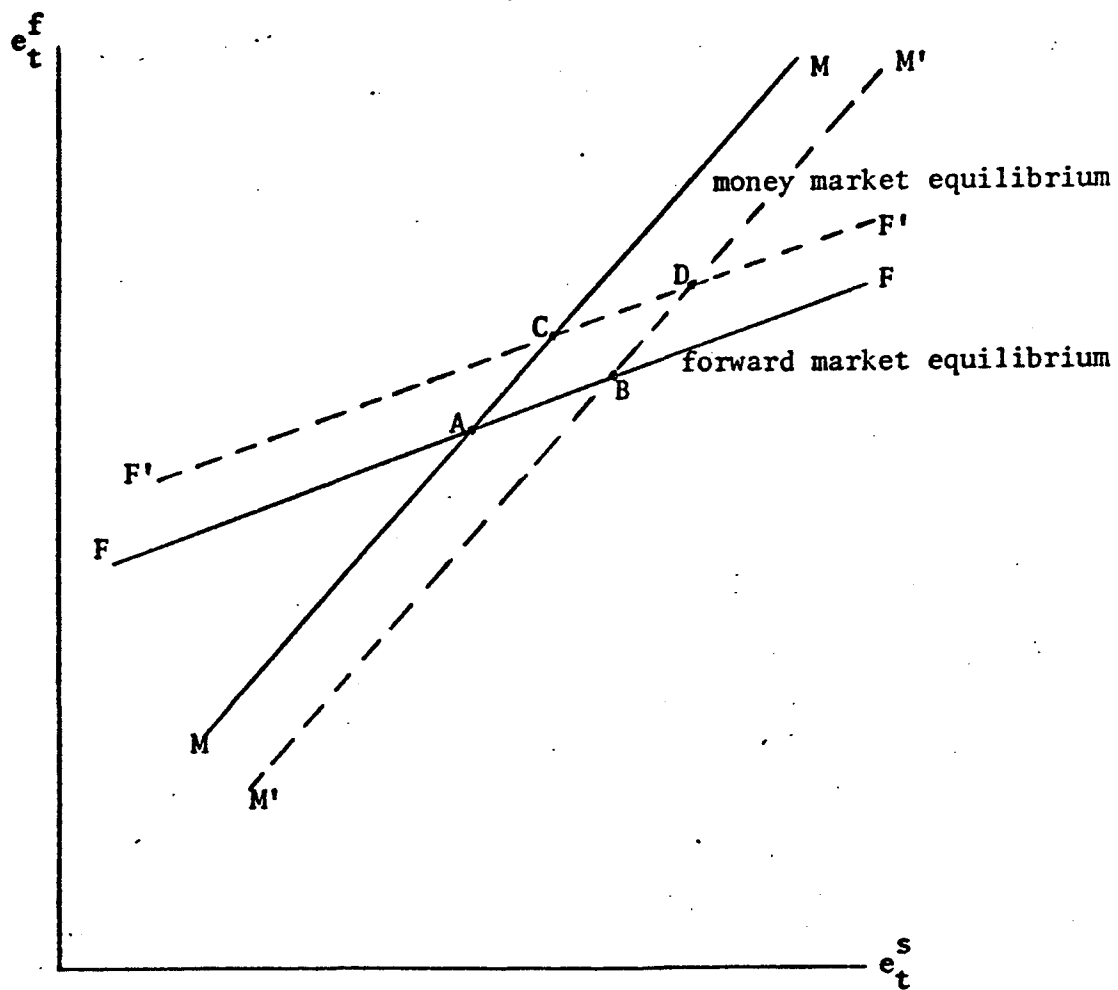


FIGURE 1



1. Two other macroeconomic models which incorporate a more general specification of speculation in the determination of forward market equilibrium are by Eaton (1978) and Harris and Purvis (1979). Both models assume full employment so that the income effects of various disturbances cannot be analyzed. Both papers also focus on situations in which current information is not fully available, and consider the information revealed by spot and forward exchange rates.
2. We find it analytically convenient to separate forward market participation into pure speculation and pure arbitrage. We implicitly treat the acquisition of an amount  $x$  of *uncovered* foreign bonds as combining a *covered* investment of  $x$  in foreign bonds and a *speculative purchase* of foreign currency forward in amount  $x$ . In a portfolio model of foreign investment we identify a third motive for participating in the forward market as hedging against domestic inflation. Forward positions for hedging purposes depend upon the relative variability of the domestic and foreign price levels and do not respond to the variables we are concerned with here. We may thus treat the forward position due to hedging as a constant absorbed in  $S_t$ ; see Eaton and Turnovsky (1980).
3.  $\gamma$  as well as other parameters of the macro model are functions of the variances  $\sigma_p^2$  etc. Elsewhere (Eaton and Turnovsky (1980)) we have shown how these  $\sigma_p^2$  variances can be generated by underlying exogenous stochastic elements of the economy.
4. The approximation in (8) is obtained as follows

$$\frac{B_t}{P_t} \approx \frac{\bar{B}}{\bar{P}} + \frac{\bar{B}}{\bar{P}} \left( \frac{B_t - \bar{B}}{\bar{B}} \right) - \frac{\bar{B}}{\bar{P}} \left( \frac{P_t - \bar{P}}{\bar{P}} \right) = \omega_3 \left( 1 + \frac{B_t - \bar{B}}{\bar{B}} - \frac{P_t - \bar{P}}{\bar{P}} \right)$$

Now 
$$\frac{B_t - \bar{B}}{\bar{B}} \approx \ln \left( 1 + \frac{B_t - \bar{B}}{\bar{B}} \right) = \ln B_t / \bar{B} = b_t - \ln \bar{B}.$$

Similarly 
$$\frac{P_t - \bar{P}}{\bar{P}} \approx p_t - \ln \bar{P} \quad \text{so that}$$

$$\begin{aligned} \frac{B_t}{P_t} &\approx \omega_3 [1 + (b_t - \ln \bar{B}) - (p_t - \ln \bar{P})] \\ &= \omega_3 [1 - \ln \omega_3] + \omega_3 (b_t - p_t). \end{aligned}$$

5. The argument follows that in footnote 4, with  $G_t/P_t^*$  in place of  $B_t/P_t$ .
6. One rationale for this procedure is obtained by imposing a transversality condition on a corresponding infinite horizon optimization problem.
7. See Turnovsky (1981) for further discussion of this issue. Elsewhere (Eaton and Turnovsky (1981)) we consider the implication of risk averse speculation for exchange rate dynamics in a model that incorporates short-run price inflexibility. See also Driskill (1980) and Driskill and McCafferty (1980).

8. A monetary expansion taking the form of an open market operation is described by  $dM + dB = 0$ , which in terms of logarithms is  $dm + (B/M)db = 0$ . In effect this is a combination of the policies discussed in Sections 4 and 5 and the various cases can be considered as an extension of these results. It is worth noting that in the absence of wealth effects ( $\omega_3 = 0$ ) an open market operation is equivalent to the monetary expansion discussed in the text.
9. See Eaton and Turnovsky (1980).

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