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VARIABILITY OF EXCHANGE RATES UNDER RATIONAL EXPECTATIONS

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1. Introduction

In the sixties and before it, it was quite commonly held view that the exchange rate is determined by supply and demand for foreign exchange and that these were determined by payments originating from the current account (or more often only from trade account) and from capital flows. It was also common to think that floating exchange rates would insulate countries from foreign disturbancies. Floating exchange rates were thought to be stable and variability of exchange rates of minor importance. In the early seventies the Bretton Woods system collapsed and empirical experiences of the floating exchange rate system could be gathered. Floating exchange rates turned out to be highly unstable in the sense that the variability of exchange rates was the main feature of the new system. There opened a new era for research work.

In the late sixties a new approach, the so-called monetary approach to the balance of payments was borne and it was connected to the new portfolio theories in the beginning of the seventies. From these ideas grew the portfolio balance theories of exchange rate determination (see Kouri & Porter (1974), Tsiang (1975), Kouri (1976) and Branson & Halttunen & Masson (1977)). These models had imperfect substitutability between assets and portfolio decisions caused the exchange rate to jump. Surpluses and deficits in the current account have an effect through wealth accumulation in time. In the seventies there was also borne the so-called monetary approach to exchange rate determination, which emphasized perfect substitutability between

* I am grateful to Kari Alho for his valuable comments.

assets and "interest parity theorem" according to which foreign and domestic interest rates could differ only by the amount exchange rate was expected to change. Then saw also light a great number of monetarist models of exchange rate determination. In this tradition exchange rate was determined by supply and demand of monies (in many models balance of payments disequilibrium is seen as a consequence of only monetary disequilibrium). In the seventies expectation formation in the form of rational expectations was added to theories of exchange rate determination (see for example the famous articles by Black (1973) and Dornbusch (1976).

We can think that imperfect asset substitutability and short term portfolio decision (and capital movements) are important in exchange rate determination. The exchange rate is determined so that asset and goods markets are in equilibrium at every point in time and in the long run the current account and wealth accumulation determine the time path of exchange rate. An important fact is that exchange rate determination is seen as a part of total macro economic, not only partial, equilibrium adjustment.

This paper presents a new version of the old "textbook version of exchange rate determination" in a dynamic context and with rational expectations. We will show that the old model still captures a bright insight into exchange rate determination process. The paper highlights three things: imperfect asset substitutability, the role of short term portfolio decisions in determining short run equilibrium and the role of current account and macro economic structure in determination of the time path of exchange rate.

2. The model

The model specified below is a small country open economy version of IS-LM model, which includes markets for domestic output and asset markets. Domestic and foreign goods are imperfect substitutes. Domestic output is determined by aggregate demand and aggregate supply. An important feature is the inclusion of expected inflation rate as an argument in domestic absorption function. However, we assume that inflation expectations are static, so the "Fisherian" real interest rate effect disappears in the model solution. Aggregate supply adjusts instantenously. The model includes domestic money, domestic government bonds, foreign bonds and foreign currency. We assume that foreign and domestic currencies are not substitutes for each other and that they are held respectively only in foreign and domestic portfolios. Both bonds are tradeable and imperfect substitutes for each other (the stocks of bonds in private portfolios can be changed instantenously, not only through current account which is the case in many popular portfolio balance models (see Branson & Halttunen & Masson (1977)). Portfolio shifts do not change net wealth, only the composition of wealth, but they affect the demand for and supply of foreign currency and so the determinaton of the exchange rate (this does not happen in models where the asset structure is not complete or the macro-economic structure affecting the asset market and expectations formation is not included in these models, see for example Branson (1982)).

Domestic money and domestic bonds are imperfect substitutes for each other and so are also domestic bonds and foreign bonds, but domestic money and foreign bonds are not substitutes for each other. Because of the small country assumption the supply of foreign bonds is infinitely elastic.

The model is as follows:

(1)	$y = A(\overset{+}{y}, \overset{-}{r-p}, \overset{+}{q}, \overset{+}{W/P}) + X(\overset{+}{q}) + A_0 + X_0$	aggregate demand
(2)	$P_D = p(\overset{+}{y})$	aggregate supply
(3)	$Y^D = Y^S$	equilibrium condition for domestic output
(4)	$q = eP^*/P_D$	terms of trade
(5)	$P = P_D^a(eP^*)^{1-a}$	consumer price index
(6)	$M = M(\overset{+}{y}, \overset{-}{r-p}, \overset{-}{q}, \overset{+}{W/P})$	import demand function
(7)	$L^D/_P = L(\overset{+}{y}, \overset{-}{r}, \overset{+}{l_D}, \overset{+}{W/P})$	domestic demand for domestic money
(8)	$B_D^d/P = H(\overset{+}{\bar{y}}, \overset{+}{r}, r^* \overset{-}{+} e, \overset{-}{l_D}, \overset{-}{l_F}, \overset{+}{W/P})$	domestic demand for domestic bonds
(9)	$eB_F^d/P = J(\overset{+}{\bar{y}}, \overset{-}{r}, r^* \overset{+}{+} e, \overset{+}{l_F}, \overset{+}{W/P})$	domestic demand for foreign bonds
(10)	$B_D^f/P_F^* = eF(\overset{+}{r}, r^* \overset{-}{+} e, \overset{+}{l^*})$	foreign demand for domestic bonds
(11)	$W = L + B_D + eB_F = D + eC + B$	marketable domestic private wealth
(12)	$Z = eC + B_D^f - eB_F^d + F^{CB}$	foreign exchange reserves of the central bank
(13)	$C = \int_{-\infty}^{t} (P_D(X+X_0)/e - P^*M + r^*B_F^d - rB_D^f/e)dt$	foreign exchange reserves of the central bank

(14) $B = B_D + B_D^f$ privately held domestic bonds

(15) $D + Z = L(.)P$ equilibrium condition of the domestic money market

(16) $B = H(.)P + eF(.)P_F^*$ equilibrium condition of the domestic bond market

Symbols:

y = domestic output (value added)

$A(.)$ = domestic absorption function

$X(.)$ = export demand function

r = domestic interest rate

p = expected inflation rate (per cent)

q = terms of trade

e = exchange rate, price of foreign currency in terms of domestic currency

P_D = price of domestic goods

P^* = price of foreign goods

P = domestic consumer price index

P_F^* = foreign consumer price index

W = marketable domestic private wealth

B = stock of domestic bonds

B_D^d = domestic bonds in foreign portfolios

B^d = domestic bonds in domestic portfolios

D = domestic component of monetary base

A_0 = autonomous component in domestic absorption

X_0 = autonomous component in export demand

a = share of domestic goods in domestic consumption

$1-a$ = share of foreign goods in domestic consumption

$M(.)$ = import demand function

l_D = shift (increase) in demand for domestic money (and shift decrease in demand for domestic bonds)

l_F = shift increase in domestic demand for domestic bonds

l^* = shift increase in foreign demand for domestic bonds

. = dot above variable means time derivative, it is $\dot{X} = dX/dt$

^ = percentage change, it is $\hat{X} = (dX/dt)/X$

r^* = foreign interest rate

C = current account cumulative surplus

Z = foreign exchange reserves of the central bank

F^{CB} = foreign exchange market interventions (stock from past), stock of foreign currency central banks has purchased.

Domestic output, price of domestic output, domestic consumer prices and domestic interest rate are endogenous short run variables, exchange rate and current account cumulative surplus are endogenous dynamic variables. Equilibrium of money market and of domestic bond market are standard, equilibrium of foreign currency market (eq. 12) is formulated according to the idea in Kouri (1980).

Foreign exchange reserves are constant at a point in time (they change only by interventions), but they change in time through current account.

We assume that inflation expectations are static, but that exchange rate expectations are perfect foresight rational expectations. This highlights the importance of rational expectations in exchange rate determination.

The model is solved by (after required substitutions) solving from goods market equilibrium condition and from money market equilibrium condition y and r as functions of other variables. According to Walras' law we do not need the equilibrium condition of the domestic bond market in solution. The solutions are linearized by Taylor approximation and then substituted into the linearized (by Taylor approximation) equations of current account, i.e. time derivative of current account cumulative surplus, and of foreign currency market equilibrium condition (eq. 12). The system can be presented in the following form:

$$\begin{bmatrix} \dot{e} \\ \dot{c} \end{bmatrix} = \begin{bmatrix} \gamma_e & \gamma_c \\ \phi_e & \phi_c \end{bmatrix} \begin{bmatrix} e \\ c \end{bmatrix} +$$

$$\begin{bmatrix} \gamma_{P*} & \gamma_{r*} & \gamma_D & \gamma_B & \gamma_{l_D} & \gamma_{F^{CB}} & \gamma_{A_0} & \gamma_{X_0} & \gamma_{l*} & \gamma_{l_F} \\ \phi_{P*} & 0 & \phi_D & \phi_B & \phi_{l_D} & \phi_{F^{CB}} & \phi_{A_0} & \phi_{X_0} & 0 & 0 \end{bmatrix} \begin{bmatrix} dP* \\ dr* \\ dD \\ dB \\ dl_D \\ dF^{CB} \\ dA_0 \\ dX_0 \\ dl* \\ dl_F \end{bmatrix}$$

For symbols see appendix I and II (note, that $\hat{e} = \dot{e}$ because we have taken Taylor approximation at point $P^* = P = P_D = e = 1$). Determinant of the state-space matrix is

$$\det(A) = \gamma_e \phi_c - \gamma_c \phi_e < 0 .$$

This is the necessary and sufficient condition for the system to have one negative and one positive eigenvalue, so we have a saddle path solution (see figure 1).

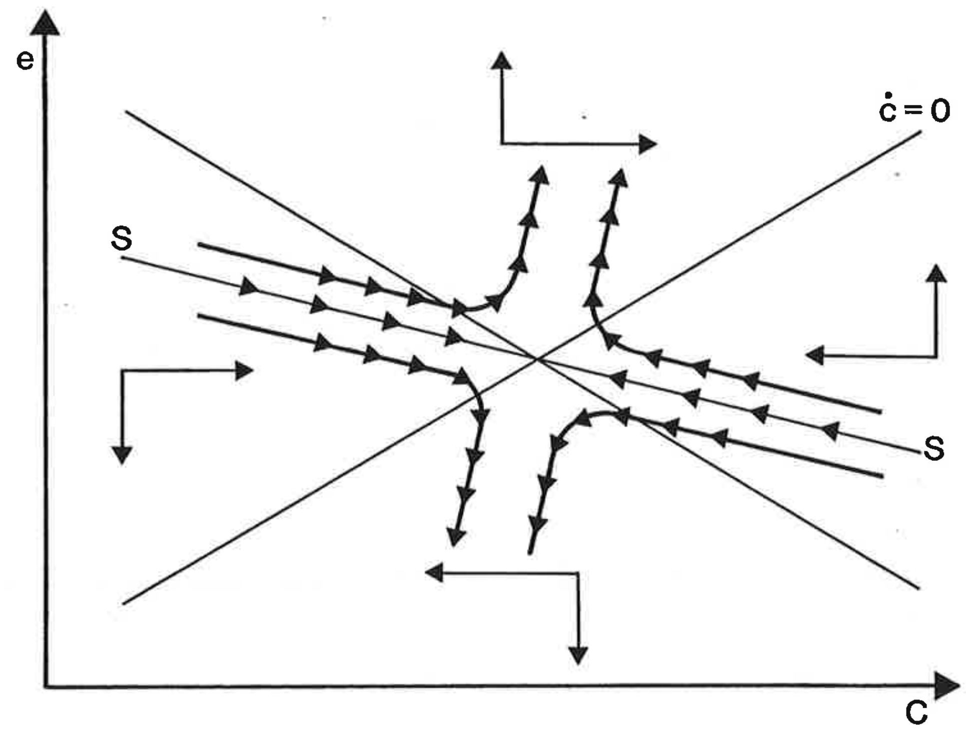

Figure 1. The saddle path solution

If current account cumulative surplus is bigger than in equilibrium (we are to the right of the $\dot{c}=0$ curve in figure 1), domestic income increases, interest rate rises and imports increase through income effect and direct through wealth effect. So to keep the current account in balance exchange rate must rise. By this reasoning we see why $\dot{c}=0$ curve must slope upwards. When wealth increases the interest rate rises and this causes oversupply of foreign currency. So to keep foreign exchange market in equilibrium the price of domestic currency must increase (or the price of foreign currency decrease). So foreign exchange market equilibrium curve must have negative slope. The saddle path (SS) has a negative slope, which can be seen from the arrows of motion in figure 1.

In region A movement goes to the right and downwards and in region C to the left and upwards. As we must always be in the saddle path (SS), we note, that when the current account is in surplus (region A) exchange rate is appreciating and when current account is in deficit (region C) we have a depreciating exchange rate. So the (long run) dynamic connection between foreign exchange market and current account (and wealth accumulation) gives us the "old textbook view" of the relationship between exchange rate and current account (this idea is sometimes called "acceleration hypothesis", (see Kouri (1983)).

3. Variability of exchange rate under various shocks

This chapter presents an analysis of exchange rate determination when the system is affected by various demand disturbances.

Let us first study the effects of an increase in the prices of foreign goods. It increases the demand for domestic goods in two respects: export demand increases and domestic demand for domestic goods increases. There are two automatic stabilizers in the economy, increase in the domestic interest rate and increase in the domestic price level. Both affect to the same direction and decrease aggregate demand. We can assume then that when the foreign prices increase export demand increases more than imports (which increases because income increases), so current account is in surplus and to equilibriate it the exchange rate must decrease, when wealth is constant. The $\dot{c}=0$ curve must move to the right. Domestic interest rate has risen, so there is excess demand for domestic currency and to equilibriate the foreign exchange market the exchange rate must decrease (the price of the domestic currency must increases). If we assume that the interest rate channel works more forcefully in stabilizing the economy than does the price level, $\dot{e}=0$ curve moves more than $\dot{c}=0$ curve and we have overshooting of exchange rate (see figure 2 a). To equilibriate the foreign exchange market exchange rate must first jump down in so large an extent that expectations of a depreciating exchange rate emerge.

We can also imagine that domestic prices stabilize domestic production in a greater extent than does domestic interest rate. Then the $\dot{e}=0$ curve does not shift much and we have undershooting of the exchange rate. Exchange rate must jump down, but not enough to equilibriate current account, so there remains expectations of appreciating exchange rate, see figure 2 b. We can assume, that the former case with exchange rate overshooting is more realistic.

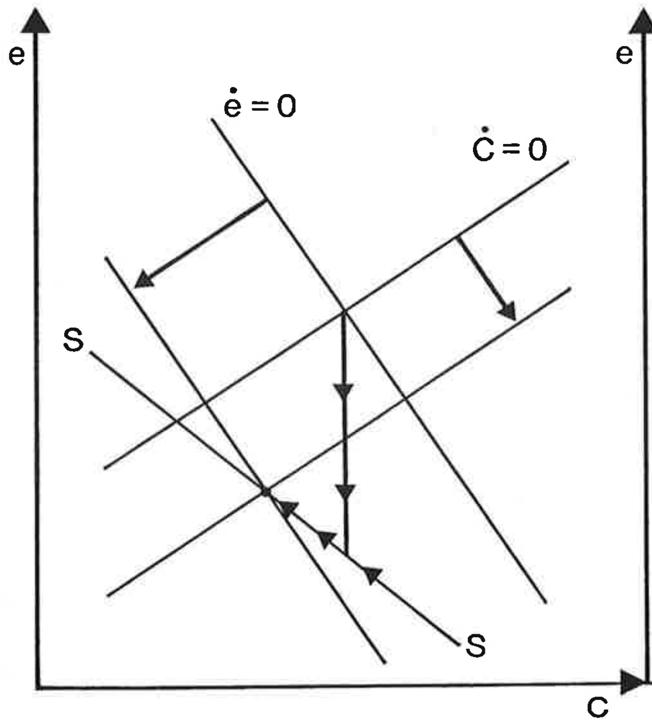

Figure 2 a.

Increase in foreign price level; the case of exchange rate overshooting

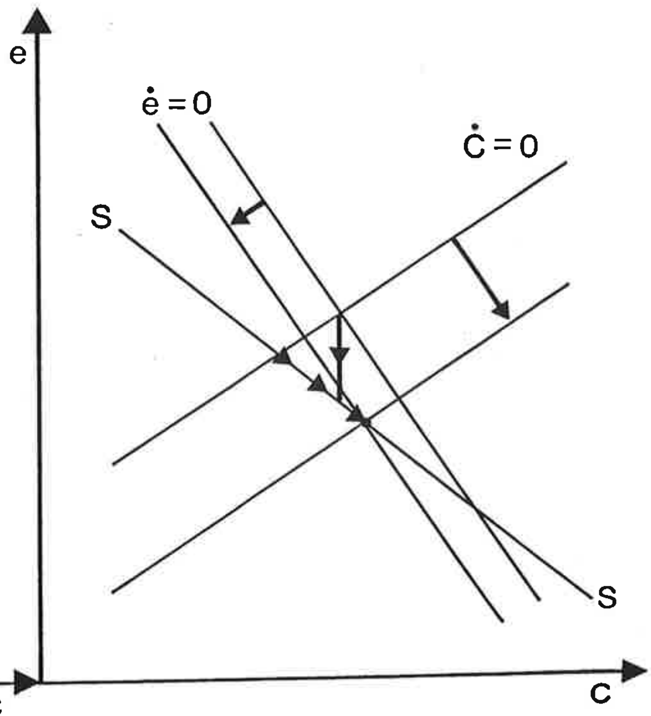

Figure 2 b.

Increase in foreign price level; the case of exchange rate under- shooting

An increase in the domestic demand for domestic goods increases domestic income and in this way import demand and so current account turns into deficit. To equilibriate current account at constant wealth exchange rate must depreciate and so $\dot{c}$=0 curve moves to the left. Domestic interest rate has increased: $\dot{e}$=0 curve shifts to the left. It is probable, that equilibrium curve (we have also here the possibility that interest rate increases so little that $\dot{e}$=0 curve holds nearly its former position and we have undershooting, but probably it is not the most realistic case) and so the exchange rate jumps first down to equilibriate asset and foreign exchange markets, expectations of exchange rate depreciation build up and exchange rate rises and probably exceeds its starting level. Now exchange rate can jump to the "wrong" direction and then turn to the "right" direction, figure 3.

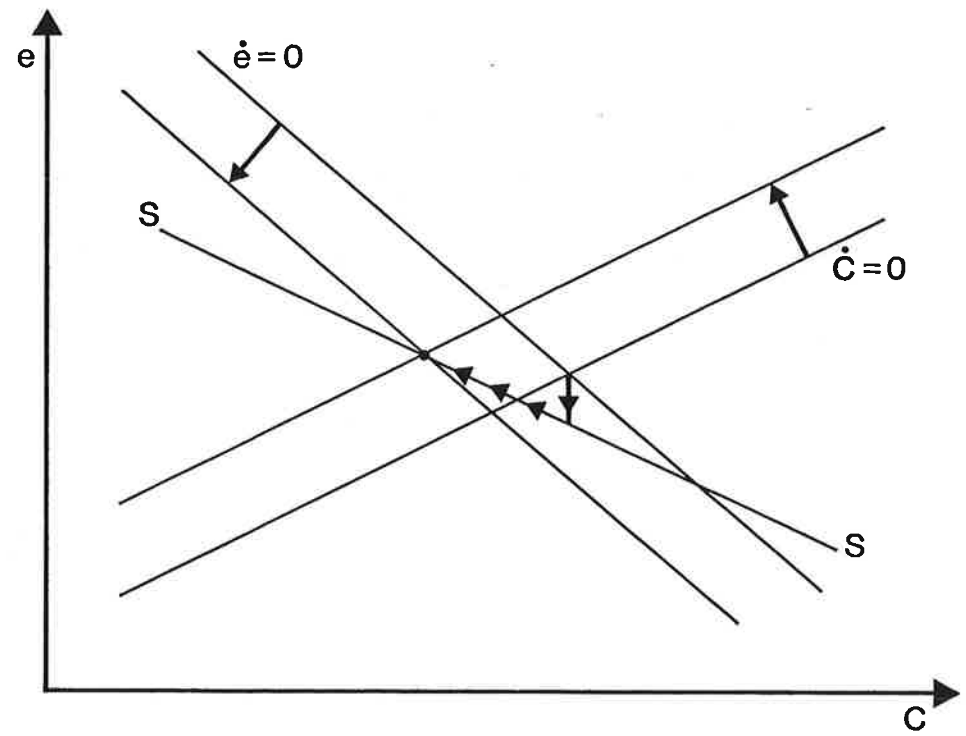

Figure 3. Rise in domestic demand for domestic goods

Increase in export demand has quite the same effects as the increase in foreign price level. The only difference is that it moves (by definition) $\dot{c}=0$ curve strongly to the right and it is sure in this case that undershooting of exchange rate occurs. The case is then just like in figure 2 b, where exchange rate first appreciates in a jump-like manner and then it has an appreciating time path.

One important reason for the assumption of imperfect asset subsitutability in the model is that the role of shift in preferences or the assets in private portfolios can be studied (these shifts are related to shifts in preferences or in changes in risk of assets).

Increase in demand for domestic money (and decrease in demand for domestic bonds) increases domestic interest rate and there is excess demand for domestic currency in the foreign exchange market. The $\dot{e}$=0 curve must move to the left (and it moves quite much). Because of the rise in the domestic interest rate (and decrease in domestic income) current account is now in surplus and $\dot{c}$=0 curve moves to the right, but this movement can not be very great. So the exchange rate must first appreciate in a jump-like manner and then fulfil the expectations of a depreciating time path (see figure 4).

Increase in domestic demand for foreign bonds (decrease in domestic demand for domestic bonds), increase in foreign interest rate and decrease in foreign demand for domestic bonds have similar effects. The $\dot{c}$=0 curve is not affected. Because of the shift to the foreign assets, there is excess supply of domestic currency and so its price must decrease (exchange rate must increase with wealth kept constant). The $\dot{e}$=0 curve shifts to the right and the exchange rate first depreciates and then comes some way back (figure 5).

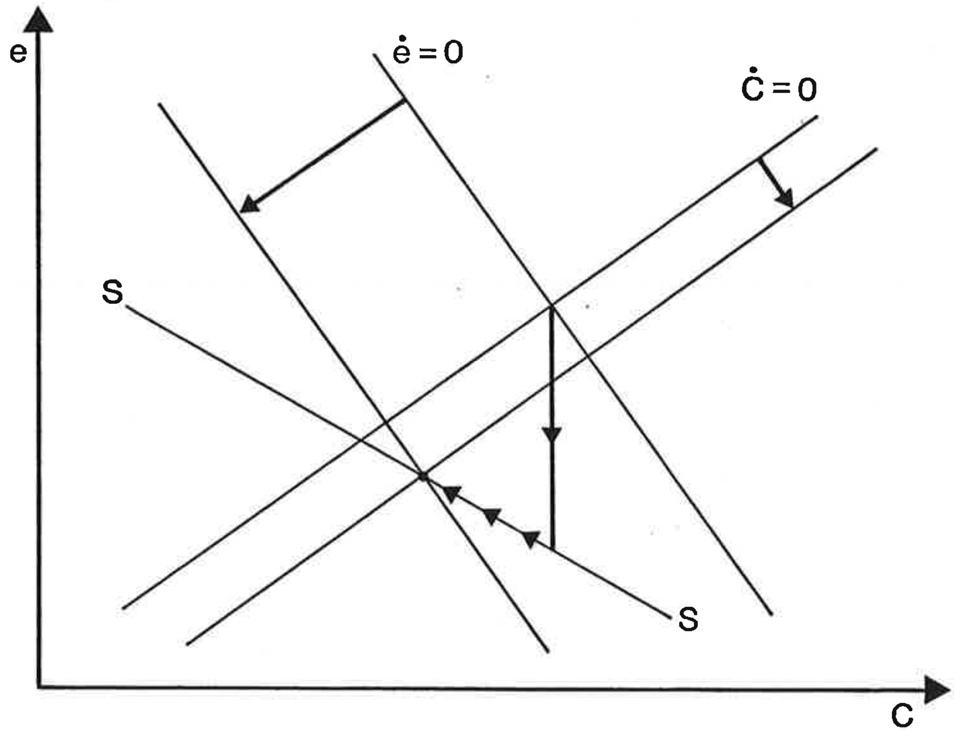

Figure 4. Increase in the demand for domestic money (and decrease in domestic demand for domestic bonds)

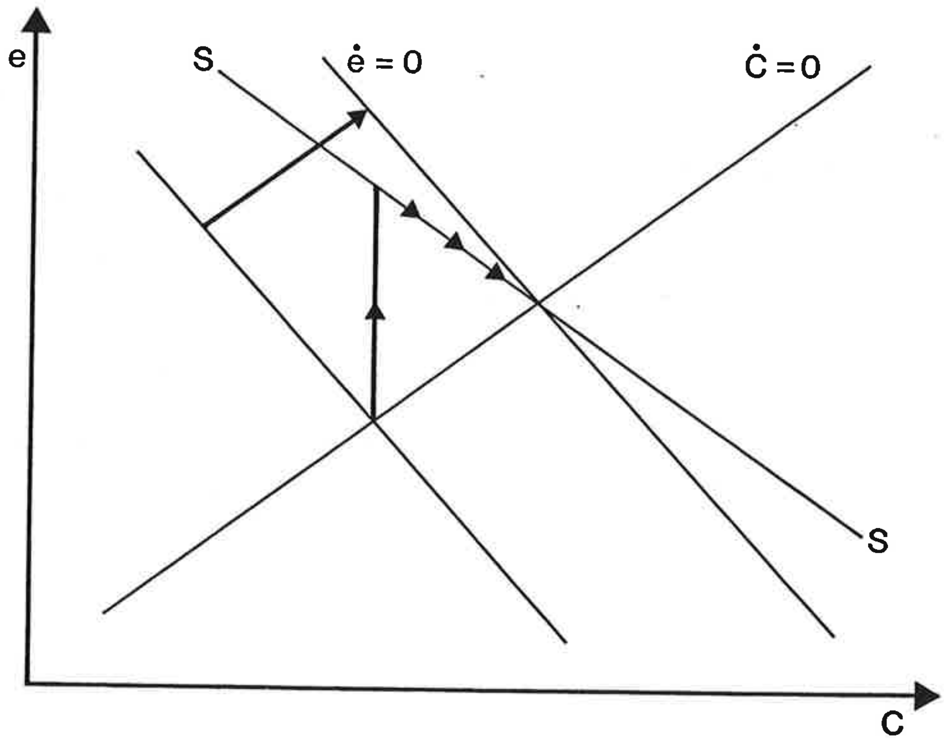

Figure 5. Increase in domestic demand for foreign bonds (and decrease in domestic demand for domestic bonds) or increase in foreign interest rate, or decrease in foreign interest rate, or decrease in foreign demand for domestic bonds

Increase in the supply of domestic money (both the "helicopter increase" and open market operation with domestic bonds) shifts $\dot{e}$=0 curve to the right (because of the falling domestic interest rate) and it also shifts the $\dot{c}$=0 curve to the left. Now it is quite clear that the equilibrium curve for foreign exchange market shifts much more than the other curve and so exchange rate first depreciates in a jump-like manner and then moves in time back (figure 6).

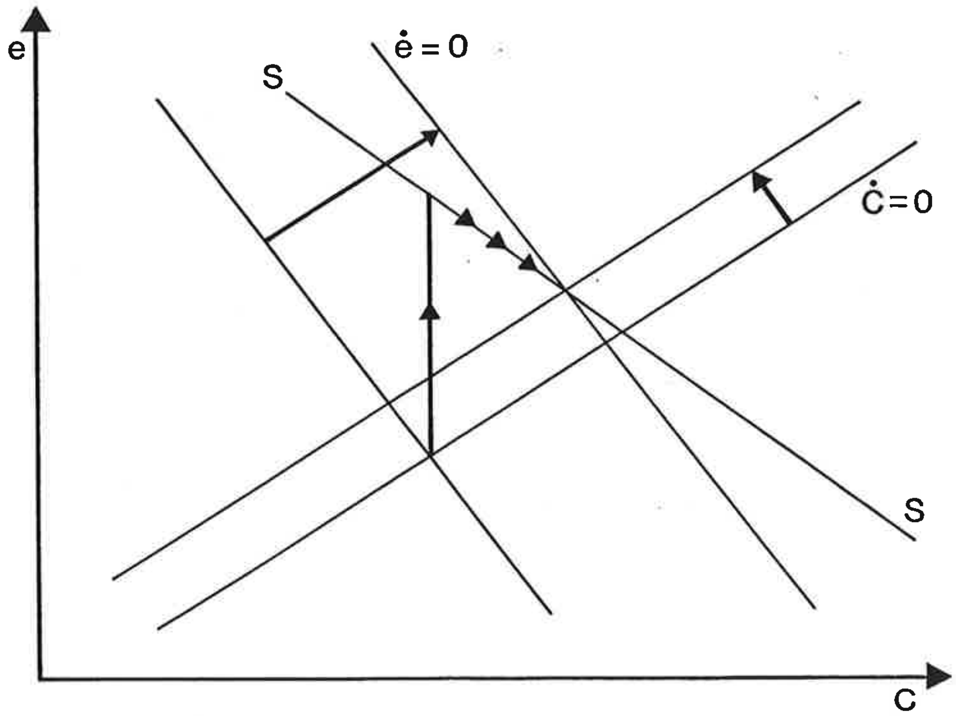

Figure 6. Increase in the domestic money supply

Intervention in the markets for foreign exchange through purchase of foreign currency causes domestic interest rate to fall, income to increase and there is excess demand for foreign currency. The $\dot{e}$=0 curve shifts to the right to equilibriate the foreign exchange market. Because income increases and interest rate falls the current account turns into deficit and the $\dot{C}$=0 curve must shift to the left. It is probable that the foreign exchange market equilibrium curve will shift more than the current account balance curve and so there is overshooting in the exchange rate and the level of exchange rate is higher in the new equilibrium than in the old one. For exchange rate policy this gives a very important lesson that when the central bank intervenes in the foreign exchange market, it is not easy to manage exchange rate directly to the equilibrium level.

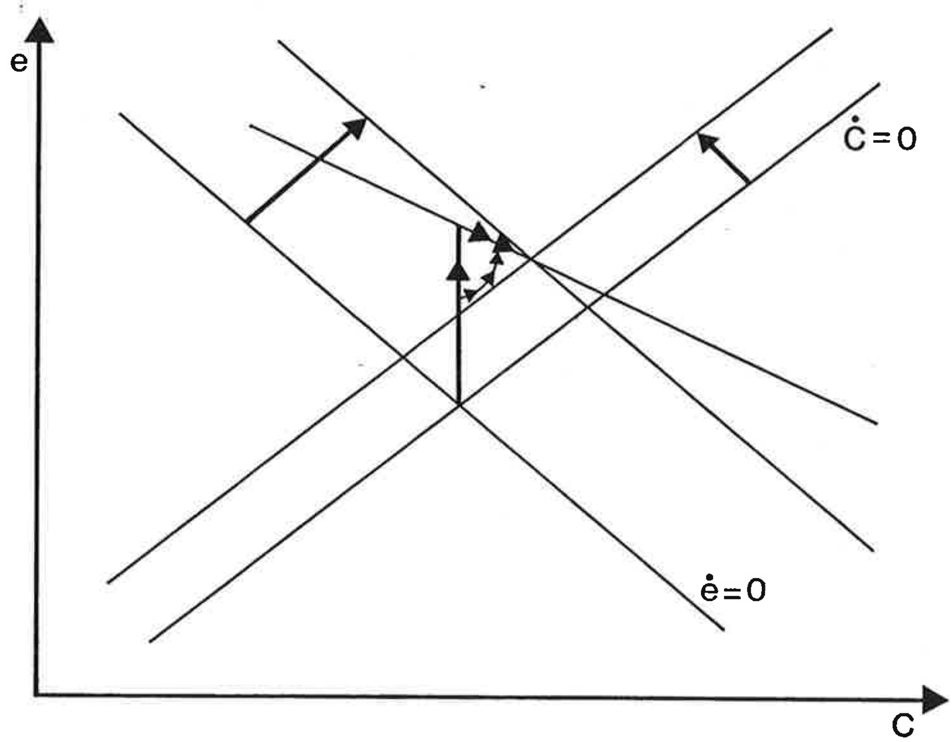

Figure 7. Central bank intervention in foreign exchange market

Notice, however, that the strategy of announcing future interventions in the foreign exchange market will reduce the exchange rate variability, because when announcement has been made the exchange rate jumps instantenously to the unstable trajectory (small bending arrow in figure 7) and the system starts a movement towards the new equilibrium with much smaller magnitude of overshooting. The same holds for the domestic money supply as has been made clear in several papers by Buiter and Miller, see for example Buiter & Miller (1981).

Note that according to our model the current account can not be an explanatory variable in the exchange rate change equation. The reason is that exchange rate and the current account are both determined simultaneously and so in many empirical studies of exchange rate behaviour inconsistent methods have been used (on inconsistency see Dhrymes (1970)). It is the whole system which must be estimated, not a single equation. By this reasoning we can also understand the existence of simultaneous current account deficit and the appreciation of the exchange rate (for example the US dollar in the middle 80's). At the same time the budget deficit grows and aggregate demand increases. This shifts both equilibrium curves to the left. But if the budget deficit is expected to grow in future, movement does not take place in the saddle path, but in unstable trajectories, so there does not take place an exchange rate overshooting and then depreciation, but gradual slow exchange rate appreciation (assuming that e=0 curve moves more than does the c=0 curve, which is empirically probable).

As we see in figure 8, as long as there are expectations of future federal budget deficits, exchange rate will appreciate. (It is assumed in figure 8 that shifts in curves take place, when the new budget is announced and that expectation formation takes place at the same time*). The high level of domestic real demand keeps current account deficit growing. Depending on the parameters of the model, there can take place exchange rate depreciation, when the budget deficit is expected to disappear, but if nothing else happens, there is no reason for dramatic exchange rate changes or jumps. (Because the future is

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* S and U curves are the saddle-paths and unstable paths associated with the announced budgets

incorporated in all past decisions in the form of rational expectations). This can be offered as a partial explanation for the quite stable US dollar appreciation before 1985 and depreciation since then. The turn in 1985 can be seen as a consequence of expectation based on the Gramm-Rudman-Hollings bill.

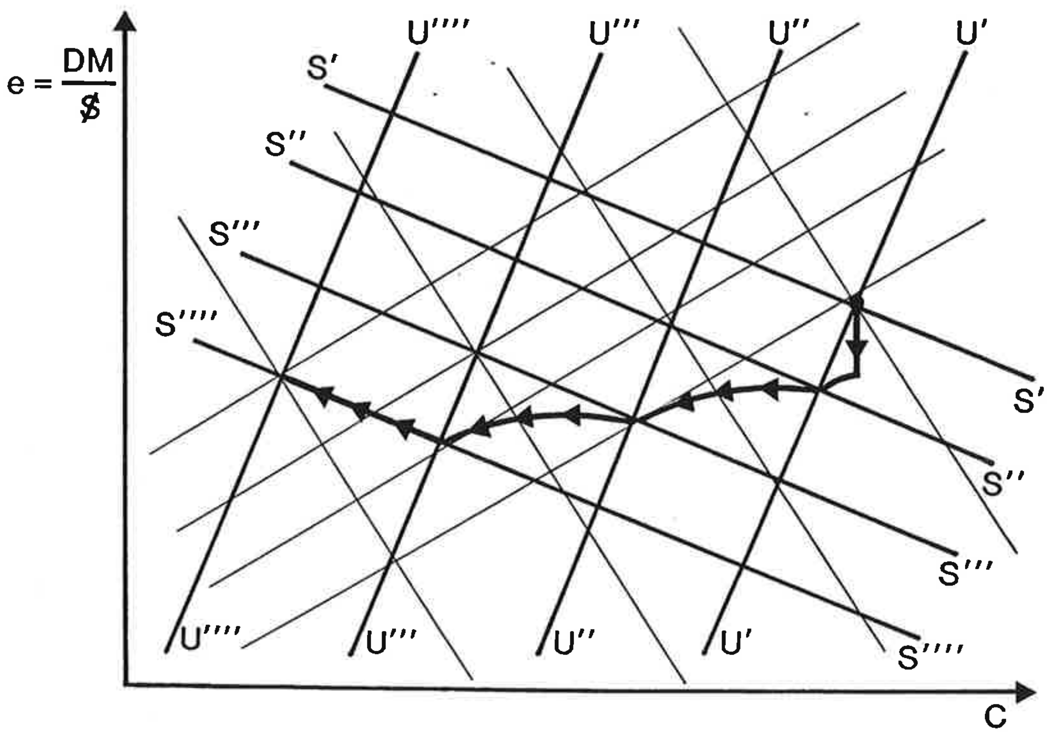

Figure 8.

Conclusions

In this paper we have presented a dynamic model for exchange rate determination with rational expectations. There have been three reasons for the analysis. First we wanted to build a model, in which short term capital movements and imperfect subsitutability between assets play a crucial role. Secondly, the role of rational expectations was studied. Thirdly, the model we have built has a clear connection with the whole macroeconomic structure and with current account. When these three elements are put together, we see that jumps in exchange rate are determined by short term portfolio decisions and that current account balance and the rate of change of exchange rate are closely related in dynamics. It is important to notice that shifts in the composition of portfolios (shifts in preferences or revaluation of different risks) can cause strong variability in exchange rates. Because these portfolio shifts are difficult to identify in time series data, it can be that they explain part of exchange rate variability that otherwise may seem irrational. On the empirical level, when specifying relationship between exchange rate and other variables great caution must be used, because this relationship consists of two elements; first jump and over or undershooting and then a path, which can go to the reverse direction than the original jump. We "tested" our model in explaining some aspects in the dollar appreciation and in the increased variance of dollar. Expected future budget deficits and increasing domestic aggregate demand explain appreciating exchange rate and shifts in composition of portfolios (revaluation of risks) can explain partly the sudden decreases in dollar rate.

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Appendix I.

$$a_{P*} = \frac{dy}{dP*} = J^{-1}\{(A_q + X_q)\alpha\, L_r + A_r(L_w - M_0)(1-\alpha)\} > 0$$

$$a_e = \frac{\partial y}{\partial e} = J^{-1}\{[(A_q + X_q)\alpha - A_w(1-\alpha) + A_wC_0]\, L_r + A_r\, [(L_w - M_0)(1-\alpha) - L_wC_0]\} > 0$$

$$a_D = \frac{\partial y}{dD} = J^{-1}\{A_wL_r + A_r(1-L_w)\} > 0$$

$$a_B = \frac{dy}{dB} = J^{-1}\{A_wL_r - A_rL_w\} > 0$$

$$a_C = \frac{dy}{dC} = J^{-1}\{A_wL_r - A_rL_w\} > 0$$

$$a_{1_D} = \frac{dy}{d1_D} = J^{-1}\{-A_rL_{C_D}\} < 0$$

$$a_{F^{CB}} = \frac{dy}{\partial F^{CB}} = J^{-1}\{A_r\} > 0$$

$$a_{A_0} = a_{X_0} = \frac{\partial y}{\partial X_0} = \frac{\partial y}{\partial A_0} = J^{-1}\{L_r\} > 0$$

$$b_{P*} = \frac{dr}{dP*} = J^{-1}\{\alpha y(L_w - M_0)(1-\alpha) - [Ly + (C_w - M_0)\alpha p_1](A_q + X_q)\alpha\} > 0$$

$$b_e = \frac{dr}{de} = J^{-1}\{\alpha y[-L_wC_0 + L_w - M_0)(1-\alpha)] - [Ly + (L_w - M_0)\alpha p_1][(A_q + X_q)\alpha$$

$$- A_w(1-\alpha) + A_w1_D]\} > 0$$

$$b_D = \frac{dr}{dD} = J^{-1}\{\alpha y + (1 - L_w) - [Ly + (L_w - M_0)\alpha p_1]A_w\} < 0$$

$$b_B = \frac{dr}{dB} = J^{-1}\{-\alpha yL_w - [L_y + (L_w - M_0)\alpha p_1]A_w\} > 0$$

$$P_1 = \frac{\partial p^d}{\partial Y}$$

A2.

$$b_c = \frac{dr}{dC} = J^{-1}\{ -\alpha y\, L_w - (L_y + (L_w - M_0)\alpha p_1)A_w\} > 0$$

$$b_{1_D} = \frac{dr}{dI_D} = J^{-1}\{ -\alpha y\, L_{1_D}\} > 0$$

$$b_{F^{CB}} = \frac{dr}{dF^{CB}} = J^{-1}\{ \alpha y\} < 0$$

$$b_{A_0} = b_{X_0} = \frac{dr}{dA_0} = \frac{dr}{dX_0} = J^{-1}\{ -[L_y + (L_w - M_0)\alpha p_1]\} > 0$$

$$J = \alpha y L_r + A_r\{ L_y + (L_w - M_0)\alpha p_1\} < 0$$

$$\alpha y = 1 - A_y + (A_w + A_q + X_q)\alpha p_1 > 0$$

Appendix II.

$$\bar{\gamma}_C = 1 - J_W + \gamma_{a_C} + (F_r - J_r)b_C > 0$$

$$\bar{\gamma}_e = C_0 + (F_0 - J_0)(1-\alpha) + J_W[(1-\alpha) - C_0] + \gamma_{a_e} + (F_r - J_r)b_e > 0$$

$$\bar{\gamma}_{P*} = (-J_0)(1-\alpha) + J_w(1-\alpha) + \gamma_{a_{PM}} + (-J_0)b_{P_M} > 0$$

$$\bar{\gamma}_{r*} = F_{r_F} - J_{r_F} < 0$$

$$\bar{\gamma}_{\hat{e}} = F_{r_F} - J_{r_F} = < 0$$

$$\bar{\gamma}_D = \gamma_{a_D} + (F_r - J_r)b_D - J_w < 0$$

$$\bar{\gamma}_B = \gamma_{a_B} + (F_r - J_r)b_B - J_w > 0$$

$$\bar{\gamma}_e = \gamma_a + (F_r - J_r)b_r > 0$$

$$\bar{\gamma}_{F^{CB}} = \gamma_{a_{F^{CB}}} + (F_r - J_r)b_{F^{CB}} - 1 < 0$$

$$\bar{\gamma}_{A_0} = \gamma_{X_0} = \gamma_{a_{A_0}} + (F_r - J_r)b_{A_0} > 0$$

$$\bar{\gamma}_{1*} = F_{1*} > 0$$

$$\bar{\gamma}_{1_F} = -J_{1_F} < 0$$

$$\gamma = (-J_0)\alpha p_1 - J_y + J_w \alpha p_1 > 0$$

$$\gamma_i = \frac{\bar{\gamma}_i}{-(F_{r_F} - J_{r_F})} \qquad (i = C \ldots 1_F$$

$$\phi_c = \phi\ a_e - M_r b_e + X_0(1-\alpha) + (X_{qM} - M_{qM})\alpha - \gamma_0 > 0$$

$$\phi_{P_M} = \phi a_{P_M} - M_r b_{P_M} + \gamma_0(1-\alpha) + (\gamma q_M - M_{qM})\alpha - M_0 > 0$$

$$\phi_D = \phi a_D - M_r b_D < 0$$

$$\phi_B = \phi a_B - M_r b_B < 0$$

$$\phi_{1_D} = \phi a_{1_D} - M_r b_{1_D} > 0$$

$$\phi_{F^{CB}} = \phi a_{F^{CB}} - M_r b_{F^{CB}} < 0$$

$$\phi_{A_0} = \overset{-}{\phi} \overset{+}{a}_{A_0} - \overset{+}{M}_r \overset{+}{b}_{A_0} < 0$$

$$\phi_{X_0} = \phi a_{A_0} - M_r b_{A_0} + 1 > 0$$

$$\phi = X_0 \alpha p_1 - M_y - (X_q - M_q)\alpha p_1 < 0$$

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