Bank of England

Discussion Paper No 20

A portfolio model of domestic and external financial markets

by

C B Briault

and

Mrs S K Howson

June 1982

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A portfolio model of domestic and external financial markets

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C B Briault

and

Mrs S K Howson

The object of this series is to give a wider circulation to research work being undertaken in the Bank and to invite comment upon it; and any comments should be sent to the Mr Briault at the address given below. The views expressed are the authors', and not necessarily those of the Bank of England.

Mrs Howson was a member of the staff of the Bank of England during 1979/81.

Issued by the Economics Division, Bank of England, London, EC2R 8AH to which requests for individual copies and applications for mailing list facilities should be addressed; envelopes should be marked for the attention of Bulletin Group.

ISBN 0 903312 45 X

ISSN 0142-6753

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Introduction[1]

1 Existing models of the links between financial markets in different countries have generally failed to capture some of the characteristic features of these markets in recent years. In particular, they have usually assumed either that spot exchange rates are fixed or that there is only one kind of money for each country which does not bear interest and is held only within and by residents of that country.[2] The latter assumption effectively rules out the existence of eurocurrency markets as well as non-resident holdings of domestic currency or bank deposits. This paper therefore outlines a model of the financial markets of a small open economy in which the interest rates on assets denominated in the domestic currency, and the spot exchange rate are simultaneously determined, without making either of those assumptions.[3]

2 In this model, non-bank asset-holders, resident and non-resident, can hold interest-bearing domestic and eurocurrency securities denominated in two currencies, whilst domestic banks issue interest-bearing deposits in both domestic and foreign currencies and lend to both residents and non-residents. The model thus incorporates a

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[1] The authors would like to acknowledge the numerous comments received on earlier versions of this paper. In particular they have benefitted greatly from discussions with Simon Babbs, Ian Bond, Gareth Evans, John Flemming, Barry Johnston, Iain Saville and John Townend of the Bank's Economics Division, while an earlier version of Section 2 was commented on by members of the International Economics Study Group.

[2] Hewson and Sakakibara (1976), Herring and Marston (1977) and Freedman (1977) model the simultaneous determination of domestic and eurocurrency interest rates on the assumption of fixed spot exchange rates; the models of Dornbusch (1978 and 1980), Branson (1979 and 1980) and Allen and Kenen (1980) determine spot exchange rates along with interest rates on financial assets on the assumption of non-interest-bearing and non-traded money. Other models of international financial markets using the portfolio-balance approach such as Dornbusch (1974) and Girton and Henderson (1976a and 1976b) make both assumptions.

[3] Johnston's (1979) model avoids both assumptions but assumes exogenous domestic interest rates in determining eurocurrency interest rates and forward exchange rates.

eurocurrency market in foreign currency, an external market in the domestic currency, and non-resident involvement in other domestic asset markets as well. In the empirical work reported in Section 3, these markets are taken to be the London portion of the eurodollar market, the eurosterling market and the markets for sterling deposits in UK banks and for British government securities.

3 Unlike most other models of the eurocurrency markets, this model does not include a separate category of 'eurobanks' which engage only in eurocurrency transactions. The domestic banks are assumed to conduct eurocurrency business at home in the foreign currency and abroad in domestic currency, via their external subsidiaries, whose balance sheets are therefore consolidated with the parent banks.

4 There have recently been some other attempts to model eurocurrency markets in a system of flexible exchange rates, notably by Henderson and Waldo (1981 and 1982) and Ghesquiere (forthcoming). The latter is concerned with the domestic and external markets for US dollars while Henderson and Waldo assume perfect substitutability between domestic and external deposits in the same currency. The model here is intended to be more general in allowing asset holders, resident and non-resident, to hold bank deposits which they may not regard as perfect substitutes.

5 In common with other models of the eurocurrency markets, this model is a model of the financial sector only. Residents' income and the current account of the balance of payments are taken as exogenous, on the grounds that whilst policy changes and other shocks affect asset markets immediately, their effects on goods markets operate with a lag. The model is therefore purely a short-run financial model.

6 The model also incorporates a version of the asset-market theory of exchange rate determination, with the spot exchange rate determined by the interaction of the demands and supplies of all domestic and foreign currency financial assets.

7 The different versions of the asset-market theory of exchange rates differ mainly in their assumptions about the mobility of capital and the formation of expectations [see Dornbusch (1978), Isard (1978), Murphy and

Van Duyne (1980)]. The model here follows Branson (1979) in assuming imperfect substitutability between comparable assets denominated in different currencies and can therefore be regarded as an attempt to extend that model to a more complex and more open financial system, where all interest-bearing domestic currency assets are internationally traded.

8 Section 2 describes the model and its theoretical predictions. These relate to the response of domestic currency interest rates and the exchange rate to monetary policy changes and to external shocks such as changes in foreign interest rates. Since the wide range of monetary assets means that there are several different monetary aggregates in the model, the section also discusses the effects of monetary policy changes on the different aggregates. Section 3 then investigates how far the theoretical predictions are borne out empirically on the basis of equations estimated from UK data for the period 1972-1979. The model can be applied to these data, which cover a period when use of the eurosterling market was constrained by UK exchange controls, because it does not assume perfect substitutability between domestic and external deposits denominated in the same currency. The results of this econometric application indicate that the theoretical model outlined in Section 2 provides a promising line of approach, although both theoretical and econometric difficulties remain, particularly with respect to the modelling of expectations and the authorities' reaction functions.

The model

9 This model of the financial sector of a small open economy is constructed according to the portfolio approach. It starts from the balance sheets of the various groups of asset holders in the economy and then derives market-clearing equations for each of the assets and liabilities these groups can hold or issue.[1] The choice of assets and liabilities in the model has been determined mainly by the desire to construct a fairly general model but, as with all portfolio models that include several assets, simplifying assumptions which may not be entirely realistic have had to be made to reduce the number of equations in the model. The balance sheets of the resident asset holders - non-banks, banks (including their external subsidiaries), and the central bank - are shown in Table A.

10 Non-bank residents are assumed to hold interest-bearing time deposits denominated in domestic currency both in domestic banks (domestic deposits) and in the external subsidiaries of domestic banks (external deposits), and also to hold interest-bearing foreign currency deposits in domestic banks (or their external subsidiaries) as well as non-interest-bearing demand deposits (denominated in the domestic currency) for transactions purposes.[2] They also hold securities denominated in both domestic and foreign currency, which are issued by other non-bank residents, by the government and by non-residents.[3]

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[1] The approach is described in Tobin (1969) and Brainard (1967). The market-clearing equations state that supply and demand in each asset market are equal in equilibrium, so their derivation consists mainly in specifying the asset demand and supply functions.

[2] Notes and coin are not included in the model.

[3] It is assumed that the country is generally an overall net creditor and that non-bank residents' net holdings of domestic currency securities and foreign currency securities are both positive. This reduces the generality of the model but, as demonstrated in Appendix 1, this facilitates the derivation of some unambiguous comparative static results.

Table A

Balance sheets

Assets(a)(b)		Liabilities(a)(b)	
Non-bank residents			
N.i.b. demand deposits	N_d^a	To banks in domestic currency	L_d^a
Domestic deposits	M_d^a	To banks in foreign currency	EL_f^a
External deposits	M_x^a	Net worth	W
Foreign currency deposits	EM_f^a		
Domestic currency securities	$S_d^a=G_d^a-S_d^f$		
Foreign currency securities	ES_f^a		
Banks			
Reserves	R_d^b	N.i.b. deposits	N_d^b
Domestic currency securities	$S_d^b=G_d^b+L_d^b$	Domestic deposits	M_d^b
Foreign currency securities	$ES_f^b+EL_f^b$	External deposits	M_x^b
		Foreign currency deposits	EM_f^b
Central bank			
Government securities	G_d^c	Reserves	R_d^c
Foreign currency securities	ES_f^c		

(a) Assets and liabilities denominated in foreign currency are valued in domestic currency by multiplying by the exchange rate E, where E is defined as the domestic currency price of foreign currency.

(b) The superscripts a,b,c and f represent non-bank residents, banks, the central bank and non-residents respectively; the subscripts d and f domestic and foreign currency respectively.

11 The domestic banks (including their external subsidiaries) borrow by issuing domestic and external deposits and foreign currency deposits to both residents and non-residents, as well as issuing non-interest-bearing demand deposits to non-bank residents. They lend to both residents and non-residents by holding domestic currency securities and foreign currency securities.[1] They also lend to the government, by holding domestic currency securities issued by the government, and hold reserve assets issued by the central bank. The central bank holds government securities and foreign currency securities (official foreign exchange reserves) against these liabilities.[2]

12 Non-residents are assumed to hold all their interest-bearing domestic assets, including foreign currency deposits, in domestic banks, and also to borrow from banks and non-bank residents of the small open economy by issuing foreign currency securities. It is also assumed for convenience that residents hold all their foreign currency deposits in domestic banks and that residents and non-residents hold external deposits in the domestic currency in the external subsidiaries of domestic banks. These two assumptions obviate the need to consider explicitly more than one banking system (non-resident banks are included along with other non-residents).[3]

13 An important feature of portfolio models of financial markets is that they recognise that asset demands and supplies will depend on the expected

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[1] This assumption amounts to aggregating over domestic currency bank loans and domestic currency securities on the one hand and over foreign currency bank loans and foreign currency securities on the other. An alternative method of simplifying the model has also been investigated, namely considering bank loans separately from securities and assuming that their rates of interest are tied to domestic and foreign currency deposit rates. This turns out to complicate the algebra while not making much difference to the results.

[2] The central bank's balance sheet will also include capital and other miscellaneous items on the liabilities side, which can be adjusted so as to maintain the central bank's other liabilities, reserve assets, unchanged in the face of changes in the domestic currency value of its foreign exchange holdings due to exchange rate changes. It is therefore assumed in what follows that exchange rate changes do not change the supply of reserve assets to the banking system.

[3] These two assumptions are not unrealistic for the 1970s, since UK residents were not allowed to hold foreign currency deposits until October 1979 (so $EM_f^a = 0$) and the eurosterling market was small.

returns or costs on all available assets. The desired holding of each of the assets by each of the private transactors will depend on the expected returns on all the other assets. It is assumed that an increase in the expected return on one asset will always increase the desired holding of that asset and reduce the desired holdings of all the other assets, that is the assets are strict gross substitutes, and it is this assumption that the asset demand and supply functions shown in Table B on page 14 incorporate.

14 The expected returns on the assets include the nominal interest rate and either the forward premium in the case of covered foreign currency assets held by residents and covered domestic currency assets held by non-residents, or the expected rate of change of the exchange rate in the case of foreign currency assets held uncovered by residents and domestic currency assets held uncovered by non-residents.

15 The nominal yields on the four categories of deposits supplied by the domestic banks or their external subsidiaries are, respectively, 0 (demand deposits), i_d (domestic deposits), i_x (external deposits) and i_f (foreign currency deposits). The expected yields of domestic and foreign currency securities are r_d and r_f.[1] The yields i_f and r_f on the two foreign currency denominated assets are assumed to be exogenously determined outside the small open economy.[2] If covered interest parity prevails in the eurocurrency markets, the forward premium on the foreign currency, fp, will be determined endogenously as the difference between the two eurocurrency rates in the model, that is $fp = i_x - i_f$.[3]

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[1] In the case of variable price securities these yields will include capital gains which will alter asset holders' wealth. However, on the grounds that these yields represent the yields of securities of several types of maturities, these wealth effects have not been explicitly included in the model, and in the empirical work of Section 3, r_d and r_f have been taken to be the yields on five-year British and US government securities respectively.

[2] In the empirical work, i_f is taken to be the three-month London eurodollar rate.

[3] This has been observed to be generally true when arbitrage between eurocurrencies is not constrained by controls on capital flows [see for example Aliber (1973), and Dufey and Giddy (1978), pages 61-71]. It was not, however, always true of the eurosterling market in the 1970s so that in the empirical work of Section 3 the forward premium has had to be taken as exogenous. In this section, it is assumed endogenous.

16 The expected rate of change of the exchange rate is $\frac{E^e - E}{E}$ where if the expected future spot exchange rate E^e is greater than the current spot exchange rate E the foreign currency is expected to appreciate against the domestic currency. E^e is taken as exogenous in the theoretical work but has of course to be proxied in the empirical work.[1] E is determined in the model.

17 Demands of non-bank residents, banks and non-residents for each of the assets thus depend on the five nominal yields (i_d, i_x, i_f, r_d, r_f) and on the actual and expected spot exchange rates (E, E^e). Non-bank residents' asset demands are also assumed to depend on wealth (W) and their demand for transactions balances (non-interest-bearing demand deposits in domestic banks) to depend on income (Y).[2] Non-bank demands for bank loans are also assumed to depend on interest rates, actual and expected exchange rates, and income. Banks' supplies of interest-bearing deposit liabilities depend on the expected yields on the assets available for them to issue or hold and thus on the five nominal interest rates and actual and expected exchange rates. Banks have also been assumed to be always willing to supply the quantity of non-interest-bearing deposits that residents demand.

18 The banks' behaviour will also depend on the supply of reserve assets. It has been assumed the domestic banks hold reserves against their domestic deposit liabilities [ie demand and time deposits denominated in domestic currency issued to residents and non-residents (N_d^b + M_d^b)], but that they (or their external subsidiaries) hold negligible reserves against eurocurrency deposits (external deposits in domestic currency and foreign currency deposits).[3]

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[1] Branson's (1979) model assumes static expectations, ie that the expected exchange rate equals the actual rate; in that case $\frac{E^e}{E} - 1 = 0$ and does not enter asset demand and supply functions. Here asset holders are allowed to expect an exchange rate different from the current spot rate but the determination of those expectations is not considered.

[2] Interest-bearing deposits are assumed to dominate non-interest-bearing deposits in all respects except as means of payment. For references to the literature on whether income or wealth should be included in demand for money functions, see Bryant (1980), pages 53-6.

[3] Thus as in Aliber's (1980) model the issuing of eurocurrency deposits reduces the banks' effective reserve ratio.

19 The domestic banks are assumed to bid for deposits to finance their lending when reserves are in short supply by raising the interest rates they are prepared to pay on interest-bearing deposits denominated in the domestic currency, so that their supplies of domestic and external deposits will be negatively related to the supply of reserve assets. The supply of domestic time deposits will also be negatively related to the quantity of demand deposits outstanding. The banks' demand for loans (domestic and foreign currency securities), on the other hand, will be positively related to the supply of reserves.[1]

20 The central bank's holdings of domestic and foreign currency securities and its supply of reserve assets to the banking system are regarded as potential policy variables.

21 The asset demand and liability supply functions are shown in Table B, where a plus or minus sign over a variable indicates the sign of the partial derivative with respect to that variable. Demands for assets denominated in the domestic currency are shown as depending positively on the current spot exchange rate, E, and negatively on the expected exchange rate, E^e, because a rise in E reduces an expected appreciation or increases an expected depreciation of the foreign currency, reducing the expected return on foreign currency assets and thus increasing the demand for domestic currency assets, while a rise in E^e works the other way, increasing an expected appreciation or reducing an expected depreciation of the foreign currency and hence reducing the demand for domestic currency assets.

22 Equilibrium in financial markets requires that the demand for each asset equals the available supply. Resident and non-resident demands for each category of deposits in domestic banks must equal

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[1] If it were simply assumed that the banks' demand for reserve assets were positively related to the relevant deposit liabilities,perverse results for the effects of a change in the supply of reserves on domestic interest rates would be obtained, because 'money' is interest-bearing, and the demand for it is positively related to interest rates. Although the positive relation of reserve assets to deposit liabilities may be true of the long run, the assumption made here is intended to capture the short-run response of the banking system to changes in the availability of reserve assets.

Table B

Asset demand and supply functions(a)

Non-bank residents

$$N_d^a = n_d^a\,(\overset{-}{i}_d, \overset{-}{i}_x, \overset{-}{i}_f, \overset{-}{r}_d, \overset{-}{r}_f, \overset{+}{E}, \overset{-}{E}^e, \overset{+}{Y})$$

$$M_d^a = m_d^a\,(\overset{+}{i}_d, \overset{-}{i}_x, \overset{-}{i}_f, \overset{-}{r}_d, \overset{-}{r}_f, \overset{+}{E}, \overset{-}{E}^e, \overset{+}{W})$$

$$M_x^a = m_x^a\,(\overset{-}{i}_d, \overset{+}{i}_x, \overset{-}{i}_f, \overset{-}{r}_d, \overset{-}{r}_f, \overset{+}{E}, \overset{-}{E}^e, \overset{+}{W})$$

$$EM_f^a = m_f^a\,(\overset{-}{i}_d, \overset{-}{i}_x, \overset{+}{i}_f, \overset{-}{r}_d, \overset{-}{r}_f, \overset{-}{E}, \overset{+}{E}^e, \overset{+}{W})$$

$$S_d^a = s_d^a\,(\overset{-}{i}_d, \overset{-}{i}_x, \overset{-}{i}_f, \overset{+}{r}_d, \overset{-}{r}_f, \overset{+}{E}, \overset{-}{E}^e, \overset{+}{W})$$

$$ES_f^a = s_f^a\,(\overset{-}{i}_d, \overset{-}{i}_x, \overset{-}{i}_f, \overset{-}{r}_d, \overset{+}{r}_f, \overset{-}{E}, \overset{+}{E}^e, \overset{-}{W})$$

$$L_d^a = l_d^a\,(\overset{-}{i}_d, \overset{-}{i}_x, \overset{-}{i}_f, \overset{-}{r}_d, \overset{+}{r}_f, \overset{-}{E}, \overset{+}{E}^e, \overset{+}{Y})$$

$$EL_f^a = l_f^a\,(\overset{-}{i}_d, \overset{-}{i}_x, \overset{-}{i}_f, \overset{+}{r}_d, \overset{-}{r}_f, \overset{+}{E}, \overset{-}{E}^e, \overset{+}{Y})$$

Banks

$$N_d^b = N_d^a$$

$$M_d^b = m_d^b\,(\overset{-}{i}_d, \overset{+}{i}_x, \overset{+}{i}_f, \overset{+}{r}_d, \overset{+}{r}_f, \overset{-}{E}, \overset{+}{E}^e, \overset{-}{R}_d^b, \overset{-}{N}_d^b)$$

$$M_x^b = m_x^b\,(\overset{+}{i}_d, \overset{-}{i}_x, \overset{+}{i}_f, \overset{+}{r}_d, \overset{+}{r}_f, \overset{-}{E}, \overset{+}{E}^e, \overset{-}{R}_d^b)$$

$$EM_f^b = m_f^b\,(\overset{+}{i}_d, \overset{+}{i}_x, \overset{-}{i}_f, \overset{+}{r}_d, \overset{+}{r}_f, \overset{+}{E}, \overset{-}{E}^e, \overset{-}{R}_d^b)$$

$$S_d^b = s_d^b\,(\overset{-}{i}_d, \overset{-}{i}_x, \overset{-}{i}_f, \overset{+}{r}_d, \overset{-}{r}_f, \overset{+}{E}, \overset{-}{E}^e, \overset{+}{R}_d^b)$$

$$ES_f^b = s_f^b\,(\overset{-}{i}_d, \overset{-}{i}_x, \overset{-}{i}_f, \overset{-}{r}_d, \overset{+}{r}_f, \overset{-}{E}, \overset{+}{E}^e, \overset{+}{R}_d^b)$$

Non-residents(b)

$$\frac{1}{E} M_d^f = m_d^f\,(\overset{+}{i}_d, \overset{-}{i}_x, \overset{-}{i}_f, \overset{-}{r}_d, \overset{-}{r}_f, \overset{+}{E}, \overset{-}{E}^e, \overset{+}{Z}_1)$$

$$\frac{1}{E} M_x^f = m_x^f\,(\overset{-}{i}_d, \overset{+}{i}_x, \overset{-}{i}_f, \overset{-}{r}_d, \overset{-}{r}_f, \overset{+}{E}, \overset{-}{E}^e, \overset{+}{Z}_2)$$

$$M_f^f = m_f^f\,(\overset{-}{i}_d, \overset{-}{i}_x, \overset{+}{i}_f, \overset{-}{r}_d, \overset{-}{r}_f, \overset{-}{E}, \overset{+}{E}^e, \overset{+}{Z}_3)$$

$$\frac{1}{E}(S_d^f + G_d^f) = s_d^f\,(\overset{-}{i}_d, \overset{-}{i}_x, \overset{-}{i}_f, \overset{+}{r}_d, \overset{-}{r}_f, \overset{+}{E}, \overset{-}{E}^e, \overset{+}{Z}_4)$$

(a) Asset demands (supplies) are formulated in terms of the holder's (issuer's) currency. (As in Table A, the superscript indicates the holder or supplier of an asset, the subscript the currency in which it is denominated.)

(b) Z_1, Z_2, Z_3, Z_4, represent exogenous factors (including foreign wealth) affecting non-resident demand for domestic assets.

the supplies of these deposits by the banks (including their external subsidiaries). Thus we must have, reckoning in domestic currency:

$$N_d^a - N_d^b = 0 \tag{1}$$

$$M_d^a + M_d^f - M_d^b = 0 \tag{2}$$

$$M_x^a + M_x^f - M_x^b = 0 \tag{3}$$

$$EM_f^a + EM_f^f - EM_f^b = 0 \tag{4}$$

23 The demand for domestic currency securities by non-bank residents, banks and non-residents must equal the supply of domestic currency securities to the market, that is the total supply of such securities less the holdings of the central bank. These securities are supplied by the government and non-banks at a common interest rate r_d in this model. Thus in equilibrium:

$$S_d^a + S_d^f + S_d^b = \bar{G} + L_d^a - G_d^c \tag{5}$$

where $\bar{G}$ is the supply of domestic currency securities by the government.

24 Foreign currency securities, on the other hand, are assumed to be in perfectly elastic supply to the residents of the small open economy, so that residents' and banks' holdings of these assets will always be equal to their demand. The supply and demand for reserve assets must also be equal in equilibrium.

$$R_d^b = R_d^c \tag{6}$$

25 Since the supply of reserve assets R_d^c is assumed to be fixed by the central bank, it can be substituted for R_d^b in the banks' demand and supply functions in the other equations. Similarly, the assumption that banks supply non-interest-bearing deposits to residents on demand means that the supply of such deposits, N_d^b, will always be equal to the demand N_d^a. Another equation, say equation 4, can also be dropped because of the balance sheet

constraints on asset holders' portfolios, that is the requirements that non-bank residents' assets minus their liabilities add up to their net worth, and that the banks' and the central bank's assets are equal to their liabilities. These constraints imply that if any three of the equations 2 to 5 are satisfied then the fourth equation is also satisfied.

26 These constraints can be written out as:

$$N_d^a + M_d^a + M_x^a + EM_f^a + S_d^a + ES_f^a - L_d^a - EL_d^a = W$$

$$R_d^b + S_d^b + ES_f^b + EL_f^b - N_d^b - M_d^b - M_x^b - EM_f^b = 0$$

$$S_d^c + ES_f^c = R_d^c$$

Adding these together and noting that $S_d^a = G_d^a - S_d^f$:

$$S_d^b = G_d^b + L_d^b, \text{ and } S_d^c = G_d^c,$$

$$G_d^a + G_d^b + G_d^c + ES_f^a + ES_f^b + ES_f^c - (M_d^f + M_x^f + EM_f^f + S_d^f) = W$$

Now $G_d^a + G_d^b + G_d^c = \bar{G} - G_d^f$; therefore:

$$\bar{G} + E(S_f^a + S_f^b + S_f^c) - (M_d^f + M_x^f + EM_f^f + S_d^f + G_d^f) = W$$

The second term on the left-hand side represents residents' claims on non-residents, the third term their liabilities to non-residents. Therefore, if EF is the domestic currency value of residents' net claims on non-residents:

$$E(S_f^a + S_f^b + S_f^c) - (M_d^f + M_x^f + EM_f^f + S_d^f + G_d^f) = EF \qquad (7)$$

$$\bar{G} + EF = W \qquad (8)$$

Insofar as F is determined as the sum of past and present current account surpluses it will be predetermined and can be regarded as an exogenous variable.[1] Equation 8 can be substituted for W in equations 2 to 5. It states that the net wealth of the community as a whole consists of government securities (an asset against which it is assumed that there is no corresponding liability) and residents' net claims on non-residents.[2]

27 The system can be reduced further by making r_d, the nominal interest rate on domestic currency securities, exogenous. This rate is at least partly exogenous to this model in that it will be affected by inflation expectations and/or real factors not included in the model. It is therefore convenient to assume that the central bank conducts its open-market operations in domestic securities so as to achieve a target rate of interest on these securities.[3] We are then left with three equations (2, 3 and 7) with the domestic and external deposit rates, i_d and i_x, and the spot exchange rate, E, as implicit arguments. Substituting in the asset demand and supply functions from Table B, these equations are:

$$m_d^a + Em_d^f - m_d^b = 0 \tag{2}$$

$$m_x^a + Em_x^f - m_x^b = 0 \tag{3}$$

$$(s_f^a + s_f^b + Es_f^c) - E(m_d^f + m_x^f + m_f^f + s_d^f + s_d^f) - EF = 0 \tag{7}$$

---

[1] F is not completely predetermined because exchange rate changes will change the foreign currency value of assets denominated in domestic currency held by non-residents (M_d^f, M_x^f, S_d^f and G_d^f) but the assumption made earlier (footnote [3] on page 8) that the country is generally an overall net creditor implies that these changes will not be large enough to change the sign of F and therefore will not alter the theoretical predictions of the model. Interest rate changes may also change the value of F by changing the market price of variable-price securities but these wealth effects have been ignored (compare footnote [1] on page 11). In the empirical work these problems can be overcome by including the foreign currency value of residents' net foreign asset position at the end of the previous period, which is a predetermined variable.

[2] This follows from the fact that all money is inside money in this model, except that backed by foreign currency securities held by the central bank (which is included in net foreign assets).

[3] This formulation does not preclude the setting of monetary targets by the authorities, since central banks have usually chosen to use interest rates to try and control monetary aggregates. In that case r_d would be chosen as the rate which, on the basis of an estimated demand for money function, is thought to be consistent with the target value of the relevant aggregate.

28 If these three equations are satisfied then the financial markets of the small open economy will be in equilibrium. These three equations can be used to predict changes in the endogenous variables that will result from changes in the exogenous variables. The endogenous variables include the yields on domestic and external deposits and the spot exchange rate. The exogenous variables include interest rates on foreign currency assets, the expected exchange rate, and the net foreign asset position (F), as well as monetary policy variables.

Predictions of the model

29 The comparative statics results on the direction of changes in the equilibrium values of i_d, i_x and E in response to changes in the exogenous variables are given in Appendix 1 and summarised in Table C.[1] Three sets of results are considered here: for central bank policy actions, external shocks (changes in foreign interest rates and shifts in non-resident demand for domestic assets), and changes in the country's net foreign asset position.

30 The instruments of monetary policy in this model are the central bank's supply of reserve assets, R_d^c, to the banking system and the rate of interest on domestic currency securities, r_d. The central bank can change the supply of reserve assets by changing its holdings of domestic currency (government) securities or of foreign currency securities and can thus intervene in both the domestic money markets and the foreign exchange market. In both cases the effect of a central bank purchase of securities will be to lower the domestic and external deposit rates i_d and i_x and to raise the exchange rate E. A reduction in the supply of reserve assets would have the opposite effects.

31 A central bank purchase (sale) of domestic currency securities will also lower (raise) the rate of interest on such securities, r_d (unless there is simultaneously an offsetting change in the demand for domestic currency securities). The fall in r_d will also lower

[1] The comparative statics results are derived on the assumption that the system is locally stable, ie that after a small displacement from equilibrium the system will return to an equilibrium position.

Table C

Predicted effects of changes in exogenous variables on the domestic and external deposit rates and the spot exchange rate

	di_d	di_x	dE (a)	
$dR_d^c = dG_d^c$	−	−	+	(dr_d=0)
$dR_d^c = d(ES_f^c)$	−	−	+	(dr_d=0)
dr_d	+	+	−	
di_f	+	+	−	
dr_f	?	?	?	
dE^e	?	?	?	
dZ_1	?	?	?	
dZ_2	?	?	?	
dZ_3	+	+	−	(di_f=0)
dZ_4	+	+	−	(dr_d=0)
dF	+?	+?	−? (b)	
dG	−	−	+	(dr_d=0)
dY	−	−	+	(dr_d=0)

(a) A positive sign for dE means a rise in the domestic currency price of the foreign currency, ie a depreciation of the domestic currency.

(b) A question mark after a sign indicates a likely but not certain outcome.

domestic and external deposit rates and depreciate the domestic currency (raise E). These changes in interest rates and the spot exchange rate will change desired, and hence actual, asset stocks including the money supply; these changes are discussed further below.

32 With respect to changes in foreign interest rates, a rise in the interest rates on foreign currency deposits, i_f, will raise the interest rates on domestic and external deposits and lower the exchange rate. However, the effects of a rise in the interest rate on foreign currency securities, r_f, are unclear. Again the rise in r_f tends to raise the interest rates on domestic and external deposits and thus to appreciate the currency (lower E), but at the same time the increase in the demand for foreign currency securities due to the rise in their expected yield causes a capital outflow which tends to depreciate the currency (raise E). The new equilibrium configuration of expected yields on domestic currency assets may involve a lower or a higher exchange rate than before the rise in r_f. A similar ambiguity arises for the effect of a rise in the expected exchange rate E^e since this too raises the expected return on foreign currency securities.

33 An autonomous rise in non-resident demand for domestic or external time deposits ($dZ_1 > 0$ or $dZ_2 > 0$) or for all domestic currency assets (dZ_1, dZ_2, $dZ_4 > 0$) implies a capital inflow which tends to appreciate the domestic currency but also to lower domestic and external deposit rates which offsets the appreciation, so that the overall effect on the domestic and external deposit rates and the exchange rate is uncertain. However, an increase in non-resident demand for foreign currency deposits in domestic banks ($dZ_3 > 0$) or for domestic currency securities ($dZ_4 > 0$) will, given the structure of the model, raise the domestic and external deposit rates and lower the exchange rate. This occurs because the rates on such assets are exogenous and do not fall in response to increased demand.

34 If the net foreign asset position (F) rises due to a current account surplus there will be an increase in residents' demands for foreign currency assets and/or a fall in non-residents' demands for domestic assets (see equation 7). Domestic interest rates would therefore tend to rise and hence the domestic currency to appreciate. However, a rise in F also implies an

increase in residents' wealth and hence in their demand for all assets. This would by itself lower domestic interest rates and depreciate the currency. Thus, if wealth effects are relatively small, a rise in F will raise the domestic and external deposit rates and appreciate the currency (lower E).

35 Two other theoretical results are reported in Table C: increases in the supply of government securities, G, and in nominal income, Y, are both shown as lowering interest rates and depreciating the domestic currency. However, in both cases the results are derived on the assumption of an unchanged interest rate on domestic currency securities, r_d, and therefore reflect only part of the effect of the change in G or Y. An increase in the total supply of government securities, G, would tend to raise r_d and hence raise other interest rates and appreciate the currency as well as raising residents' net wealth whose effects on interest rates and the exchange rate operate in the opposite direction.

36 An increase in income also has at least two effects. It raises the transactions demand for non-interest-bearing domestic currency deposits by non-bank residents; given an unchanged supply of reserve assets to the banking system, and the assumption that domestic banks supply non-interest-bearing deposits on demand, this will reduce the banks' supply of interest-bearing domestic deposits, tending to lower the interest rates on domestic and external deposits.[1] However, a rise in income will also raise the demand for loans and tend to push up the domestic currency securities rate, r_d, and other domestic interest rates.

Monetary policy

37 A contractionary monetary policy, which involves a reduction in the reserve base of the banking system and/or a rise in the rate of interest on domestic currency securities, will both raise the domestic and external deposit rates and appreciate the currency. These changes in interest rates will be accompanied by changes in asset stocks including those that make up the monetary aggregates. Since

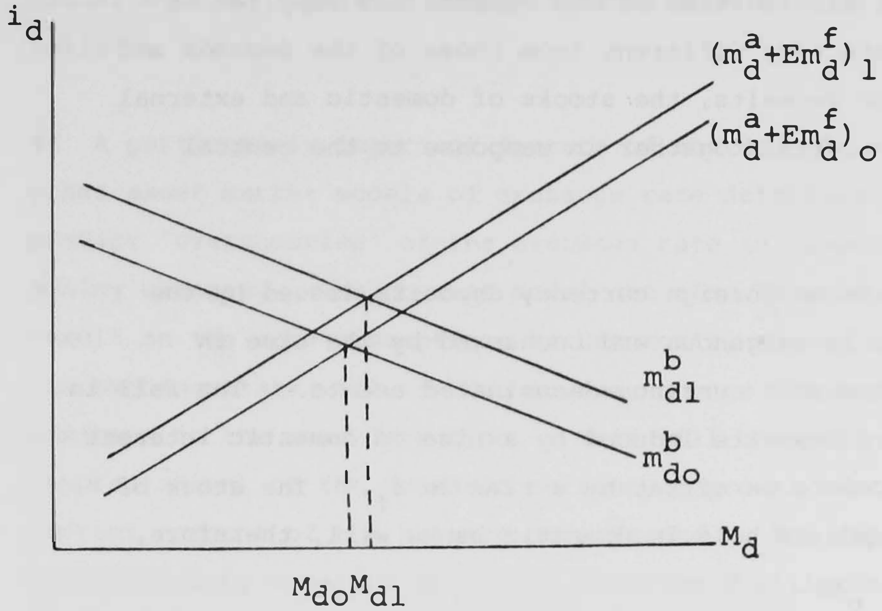
[1] This result also holds when non-bank residents' demand for interest-bearing deposits are functions of income (as well as of wealth).

the demand, and hence the supply, for non-interest-bearing demand deposits depends negatively on interest rates and positively on the exchange rate (Table B), it will fall; hence the narrow monetary aggregate M1, which is equal in this model to the stock of non-interest-bearing deposits held by residents (N_d^a), will definitely fall as a result of the central bank's actions. However, the bank deposits which make up the broader monetary aggregates bear interest. Their demand depends positively on interest rates, so that the effect of a contractionary monetary policy on the broader monetary aggregates is less than clear than that on the narrow aggregate.

38 Several broad monetary aggregates can be defined in this model. These include residents' demand and time deposits in domestic currency in domestic banks ($N_d^a + M_d^a$) which is equivalent to sterling M3, residents' total deposits in domestic banks including foreign currency deposits ($N_d^a + M_d^a + EM_f^a = M3$), and their total domestic currency deposits ($N_d^a + M_d^a + M_x^a$), as well as a range of aggregates which also include non-residents' deposits denominated in domestic currency or held in domestic banks. To see how these react to a tight monetary policy it is necessary to consider the responses of the demand and supply of the component deposits to a rise in the domestic currency securities rate, r_d, and a fall in bank reserves, R_d^b.

39 A rise in r_d will reduce the demands, by residents and non-residents, for domestic and external deposits, and increase the banks' willingness to supply these deposits (Table B). A reduction in the supply of reserves to the banking system will also tend to increase the supply of domestic and external deposits as banks bid for these deposits to finance their lending. The own rates of interest on these deposits will rise and in each case the rise in the competing rate on the other deposits and the fall in the exchange rate will also reduce non-bank resident and non-resident demand and increase the banks' supply. The stocks of domestic and external deposits will then rise or fall depending on whether the increase in the banks' supply is greater or less than the reduction in demand (see Diagram 1).

Diagram 1



(m_d^a + Em_d^f is the demand for domestic deposits by residents and non-residents respectively, m_d^b the supply of domestic deposits by domestic banks. Both curves shift as a result of the central bank's actions.)

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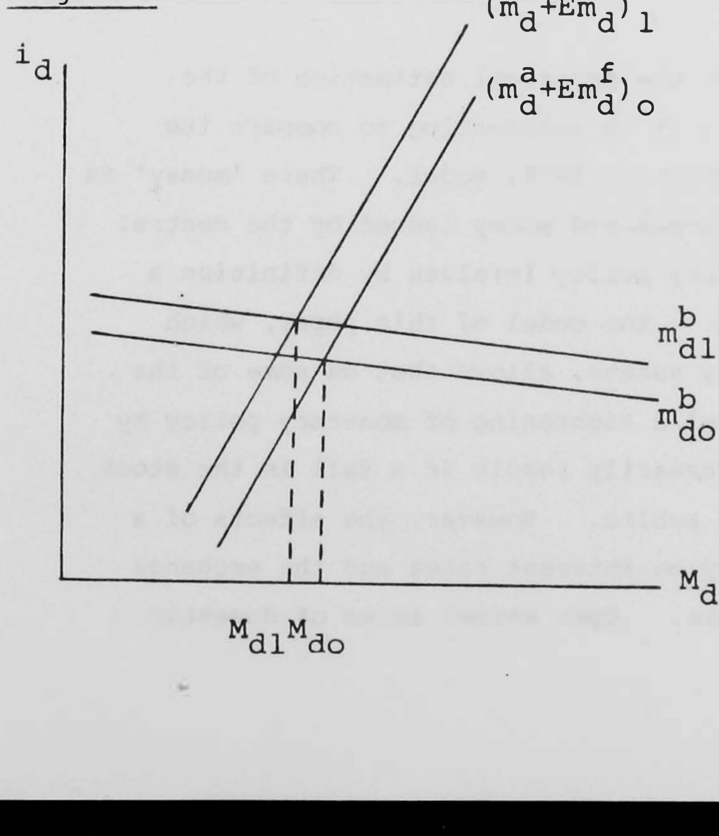
40 The more elastic are the supplies of domestic and external deposits and the less elastic the demands with respect to their own and competing rates of interest, the more likely are the stocks of these deposits to fall in response to a rise in interest rates generally (see Diagram 2).

Diagram 2



Unless the interest elasticities of the demands and supplies of external deposits are very different from those of the demands and supplies of domestic deposits, the stocks of domestic and external deposits will rise or fall together in response to the central bank's actions.

41 The interest rate on foreign currency deposits issued by the domestic banks, i_f, is exogenous and unchanged by the rise in interest rates on domestic currency denominated assets. The fall in the demand for these deposits induoed by a rise in domestic interest rates will not therefore be offset by a rise in i_f. The stock of foreign currency deposits held in domestic banks will, therefore, definitely fall.

42 The outcome of these changes for the broad monetary aggregates will, of course, depend on the relative magnitudes of the changes in the different categories of bank deposits. Residents' domestically-held domestic currency deposits, that is sterling M3 in the UK case, will fall if residents' holdings of domestic deposits (M^a_d) do not rise or rise by less than the fall in Ml (their non-interest-bearing domestic deposits, N^a_d), and will rise if the rise in M^a_d exceeds the fall in N^a_d. However, since residents' holdings of foreign currency deposits will fall, residents' total deposits in domestic banks, or M3, will rise by less than a rise in sterling M3 and is therefore more likely to fall as a result of a contractionary monetary policy.

43 Before turning to consider the empirical estimation of the theoretical model in Section 3 it is interesting to compare its predictions with those of Branson's (1979) model. There 'money' is only non-interest-bearing high-powered money issued by the central bank; a contractionary monetary policy involves by definition a reduction in the money supply. The model of this paper, which includes a variety of monetary assets, allows that on some of the possible definitions of 'money' a tightening of monetary policy by the central bank will not necessarily result in a fall in the stock of money held by the non-bank public. However, the effects of a contractionary monetary policy on interest rates and the exchange rate are similar in both models. Open market sales of domestic

currency securities do not (initially) change residents' wealth in either model. Domestic interest rates rise and the exchange rate falls.

44 A particularly important feature of the Branson model and of other asset market models of exchange rate determination is that they predict 'overshooting' of the exchange rate in response to monetary policy changes. The present model can also be used to derive this result on the same assumptions as Branson's, namely that a change in the exchange rate will, in due course, change the net foreign asset position in the same direction. This will occur if a depreciation (appreciation) of the domestic currency improves (worsens) the current account of the balance of payments. The impact effect of a contractionary monetary policy in lowering E will then, over time, reduce residents' net foreign asset position. As F falls, E rises again, since $\frac{dE}{dF} < 0$ (see Table C). The final equilibrium level of E will be higher than the level of E immediately after the tightening of monetary policy; hence the domestic currency at first appreciates above its own equilibrium value and then falls back. However, in this model $\frac{dE}{dF} < 0$ only if wealth effects are not large; the fall in residents' net wealth implied by the fall in F might be sufficiently large to maintain domestic interest rates and hence the value of the domestic currency at a high level. Thus it is less certain in this model than it is in Branson's model that the initial appreciation of the domestic currency in response to a tightening of monetary policy will in due course be reversed.

An empirical application of the theoretical model

45 This section reports the results of econometric work based on the theoretical model outlined above. The three-equation model (equations 2, 3 and 7) from which the theoretical comparative statics results were derived is equally suitable as a framework for econometric investigation, with the domestic deposit rate, the external deposit rate (for the domestic currency) and the spot exchange rate as the three endogenous variables.

46 Using the notation introduced above we may write the model as:

$$i_d = f_1(i_x, E, z) \quad (9)$$

$$i_x = f_2(i_d, E, z) \quad (10)$$

$$E = f_3(i_d, i_x, z) \quad (11)$$

where z is a vector denoting the set of predetermined variables, included lagged values of the three endogenous variables. The exogenous variables suggested by the theoretical model include the yields on domestic currency and foreign currency securities, the foreign currency deposit rate, the expected exchange rate, the net foreign asset position, nominal income, wealth and the factors affecting non-resident demand for the various assets included in the model. An empirical estimation of these three equations permits us to derive, within the context of a three-equation model, quantitative estimates of the effect of changes in the exogenous variables on the three endogenous variables. These empirical results may then be compared with the theoretical comparative statics results reported above in Table C.

47 The estimation of the three-equation model (equations 9 to 11) as stated above is made difficult by identification and simultaneity problems. Therefore the model is estimated in a reduced form whereby

each of the three endogenous variables is regressed only on the set of predetermined variables.[1] Although it could not be claimed that stable relationships suitable for policy purposes have been discovered, the empirical results are at least encouraging in that the theoretical outcome of changes in the exogenous variables were generally replicated in the empirical work.

The data

48 For the purposes of the econometric work, the small open economy analysed in the theoretical model is taken to be the United Kingdom, because of the presence of the appropriate financial assets denominated in sterling and because the United Kingdom meets the requirement of the theoretical model that the residents of the domestic economy hold a positive (or small negative) net foreign asset position. In addition, since the theoretical model allows for imperfect asset substitutability, the presence of exchange controls and the consequent restrictions on arbitrage between the internal and external financial markets during the estimation period (1972-1979) do not constitute a serious difficulty in adopting the theoretical model as a framework for the econometric work.

49 The data used are the three-month domestic sterling inter-bank rate, the three-month eurosterling rate, the sterling/dollar spot exchange rate,[2] the three-month eurodollar rate, the three-month forward premium on the dollar against sterling, the secondary market yields on UK and US government bonds with five years to maturity, the net foreign asset position (in dollars) of UK residents and UK nominal GDP.[3][4]

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[1] Estimation of the structural form of the model using simultaneous equation techniques was also attempted, having imposed prior restrictions on each equation in order to identify the system. The results proved to be little different to those derived from reduced form estimation, while the apparent degree of simultaneity present was less than might have been expected in such a system.

[2] Using the sterling/dollar exchange rate rather than the dollar/sterling exchange rate maintains compatability with the definition of 'E' in the theoretical model.

[3] Data sources are given in Appendix 2.

[4] Decomposing nominal GDP into real and deflator components did not improve the econometric results.

50 A suitable proxy for the expected exchange rate was not immediately evident and attempts to use various alternative weighted averages of past values of the exchange rate proved to be no more successful than the inclusion only of its value in the previous period. Thus the expected exchange rate does not enter the empirical model as an independent variable, although the specification adopted here is comparable with the approach of Bilson (1978) where a lagged exchange rate term is included because the actual exchange rate is assumed to adjust towards its 'equilibrium' value through a simple partial adjustment mechanism. This specification, being an imperfect substitute for the complete modelling of exchange rate expectations, does mean that the estimated coefficients must be interpreted with care. Similarly, as in the theoretical model, the absence of the authorities' reaction functions for both interest rates and the exchange rate may influence the results.

51 Most of the estimation was carried out using quarterly data. For this, quarterly averages of all the series were used with the exception of the net foreign asset position, where the level at the end of the previous quarter was utilised.[1] These end-quarter levels were derived from the annual net foreign asset series and the quarterly current account data. However, because of the limited estimation period, and in an attempt to increase the power of parameter stability tests outside the estimation period, estimation was also performed using monthly data. For this, end-month interest and exchange rates were used while the net foreign asset position and GDP variables were interpolated from the quarterly data.[2]

52 The estimation period was constrained by the floating of sterling in June 1972 and the abolition of exchange controls in October 1979. Thus the longest estimation periods ran from 1972 Q2 to 1979 Q3 (quarterly data) and from 1972 May to 1979 September (monthly data). Parameter stability tests using data from 1979 Q4 to 1980 Q4 were employed in an attempt to discover any evidence for an impact

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[1] Thus F enters as a predetermined variable.

[2] The spurious frequencies introduced by this interpolation caused problems in one of the estimated equations so a proxy for monthly nominal GDP was constructed from monthly industrial production and retail prices data.

either of the abolition of exchange controls or of the subsequent lifting of the 'corset' in June 1980.

Estimation

53 The estimation began with a general dynamic specification of the model (insofar as the limited number of data observations permitted) and continued by simplifying each equation to a more specific form to the extent that these restrictions were not rejected by the data. Using quarterly data, the general dynamic specification included only a single-period lagged term in each explanatory variable, while the monthly data permitted four-period lags. F-tests were used to assess whether or not a restriction of an equation could be rejected as being unacceptable. Although this procedure is preferable to specifying a restricted version of each equation without any form of acceptability testing, it is important to note that the final form thus derived may not be unique - it is difficult to discriminate statistically between alternative options over the order in which the restrictions are imposed. It was therefore useful to appeal to the theoretical model for guidance, for example that the presumed rapid adjustment of financial markets would suggest, ceteris paribus, the elimination of insignificant lagged terms before current period terms, while the possibility of linear dependence between contemporaneous eurosterling (i_x), eurodollar (i_f) and forward premium (fp) terms suggests the desirability of including at most two of these terms as regressors at each lag length.

54 We begin with the equation for the domestic short-term interest rate, i_d. A complete listing of all the estimated equations, from the initial general form to the final parsimonious form is not presented; interesting points arising from the process of restricting the equations are noted where appropriate. In the case of the i_d equation the preferred parsimonious form estimated over 1972 Q2-1979 Q3 is shown as equation 12.[1] In the testing which led to this specification, it became evident that nominal GDP was an insignificant variable. The equation as reported appears to be reasonably well specified.

[1] Details of the reported test statistics are given in Appendix 2. t-statistics are given in parentheses beneath the coefficient estimates.

$$i_{dt} = \underset{(1.00)}{-1.105} + \underset{(3.05)}{0.543} i_{dt-1} - \underset{(1.82)}{0.269} i_{xt-1} - \underset{(2.04)}{4.806} E_{t-1} + \underset{(3.63)}{0.704} r_{dt}$$

$$+ \underset{(3.35)}{0.084} F_t + \underset{(1.63)}{0.226} i_{ft} + \underset{(3.62)}{0.370} fp_t \qquad (12)$$

OLS, 1972 Q2-1979 Q3

RSS	7.643	P(2)	2.45	Q(3)	11.45
SE	0.589	P(5)	5.90		
$\bar{R}^2$	0.951				
DW	2.11				
LB(4)	7.80				

55 Parameter stability tests on equation 12 indicated that within-sample stability was relatively poor, though the equation forecast beyond 1979 Q3 reasonably well. Thus estimating the same equation specification over a shorter data period and forecasting to 1979 Q3 indicated that although the equation estimated to 1978 Q1 or Q2 performed acceptably well, equations estimated to 1978 Q3 or Q4 significantly underpredicted the domestic short-term interest rate in 1979. This parameter instability did not, however, involve any change in the sign on any of the coefficients. Alternative specifications of the equation failed to overcome this problem so the equation is probably best viewed as typical of the relationship over the estimation period. Beyond 1979 Q3 equation 12 performs well - neither the abolition of exchange controls or the end of the corset induced parameter instability, although the presence of significant within-sample instability implies that the power of this test is low.

56 The next equation to be considered is that for the eurosterling interest rate, i_x. One immediate concern is whether or not the covered arbitrage relationship could be accepted by the data, allowing us to write the equation as $i_{xt} = i_{ft} + fp_t$. As equation 13 demonstrates, the presence of significant coefficients on terms other than the current period values of i_f and fp did not permit the restriction of the equation to its covered arbitrage formulation.

$$i_{xt} = \underset{(1.56)}{0.868} - \underset{(3.11)}{0.471} i_{xt-1} + \underset{(16.21)}{1.078} i_{ft} + \underset{(2.88)}{0.460} i_{ft-1} + \underset{(21.41)}{0.933} fp_t$$

$$+ \underset{(3.96)}{0.651} fp_{t-1} - \underset{(1.91)}{0.158} r_{dt} \qquad (13)$$

OLS, 1972 Q2-1979 Q3

RSS	2.748	P(2)	6.34	Q(3)	0.72
SE	0.346	P(5)	8.65	Q(6)	2.52
$\bar{R}^2$	0.988				
DW	2.39				
LB(4)	7.39				

57 This specification proved to be stable within sample. It is, however, difficult to interpret the result in terms of economic theory. In particular, the negative coefficient on the lagged dependent variable is problematic, although the positive coefficients on the lagged i_f and fp terms provide an interesting counterpart. Beyond 1979 Q3, however, the equation did not perform as well, with the static forecast demonstrating that equation 13 was underpredicting the actual value of i_x in the first three quarters of 1980. It is not possible to assert with complete confidence that this apparent shift in the determination of i_x is due to the abolition of exchange controls, particularly since the equation specification itself might be questioned. No further significant parameter instability was evident following the lifting of the corset at the end of 1980 Q2.

58 The covered arbitrage specification was evidently worth exploring and is reported as equation 14. The substantial increase in the residual sum of squares (RSS) over equation 13 confirms that equation 14 would be rejected by the conventional F-test as a restriction of equation 13 but the parameter stability tests yield encouraging results.[1] The parameter stability results for forecasts beyond 1979 Q3 indicate that the problems with equation 13 over 1980 may be due as much to the equation specification as to any effects of exchange controls. For both econometric and theoretical reasons,

[1] The inclusion of a constant term in equation 14 does not affect the results; indeed the constant term proves to be insignificant.

$$i_{xt} = \underset{(61.62)}{1.0025 i_{ft}} + \underset{(35.67)}{1.0089 fp_t} \quad (14)$$

OLS, 1972 Q2-1979 Q3

RSS	6.845	P(2)	0.20	Q(3)	0.03
SE	0.494	P(5)	0.55	Q(6)	2.05
$\bar{R}^2$	0.998				
DW	2.35				
LB(4)	1.48				

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equation 14 is more plausible than equation 13, although it is of interest to note that both are consistent with the general theoretical framework outlined in Section 2 and both yield similar results in the dynamic simulation exercises presented below.

59 We turn finally to the exchange rate equation, given below as equation 15. Encouragingly, the lagged exchange rate term proved to be significantly different from unity, thus suggesting that the exchange rate is not best modelled in first differences.

$$E_t = \underset{(2.46)}{0.059} + \underset{(1.58)}{0.00515 i_{dt-1}} + \underset{(5.78)}{0.01440 r_{dt}} - \underset{(2.45)}{0.00119 F_t} + \underset{(17.92)}{0.74690 E_{t-1}}$$

$$- \underset{(1.50)}{0.00341 i_{ft}} - \underset{(3.01)}{0.01054 i_{ft-1}} - \underset{(2.71)}{0.00783 fp_{t-1}} \quad (15)$$

OLS, 1972 Q2-1979 Q3

RSS	0.0035	P(2)	1.16	Q(3)	4.10
SE	0.0127	P(5)	1.75	Q(6)	5.41
$\bar{R}^2$	0.9638				
DW	2.25				
LB(4)	8.99				

60 Contrary to equations 12 and 13 for the two interest rates, each of which performed poorly either within or beyond the sample estimation period, the exchange rate equation exhibited no signs of parameter instability over the test

periods.[1] Although detailed discussion of the effect of changes in the exogenous variables on the endogenous variables must await the dynamic simulation of the complete three-equation system, it is of interest to observe the significant positive coefficient on the domestic securities interest rate, r_d, in equation 15. This might be interpreted as a proxy for an expectations effect whereby an increase in r_d indicates, ceteris paribus, a worsening of inflationary expectations in the United Kingdom and this exerts upward pressure on E, the sterling/dollar exchange rate. Alternatively, the equation may be reflecting simultaneity biases not taken into account, with changes in r_d during part of the estimation period reflecting the authorities' reaction to a change in E.

61 Having allowed the data to determine - except for equation 14 - the final form of each equation, it is profitable to comment generally on certain aspects of equations 12, 13, 14 and 15. First, the quantitative effects of the exogenous variables on the endogenous variables can be assessed adequately only within the context of a three-equation model. Second, the particular equations which certain terms enter may be less important than their impact on all three endogenous variables as determined within the model. Third, the sign and magnitude of the coefficient on a variable in an individual equation may be misleading as a guide to its overall effect, reinforcing the point that it is necessary to consider the three-equation system as a whole. We turn therefore to the results generated by the complete system.

62 This analysis involves carrying out two types of simulation. The first of these consists of a dynamic simulation - that is, with lagged endogenous

[1] As with all the reported equations this does not imply that the coefficients of the equation are stable over the entire estimation period. The results of Hacche and Townend (1981), who concluded that a stable exchange rate equation could not be derived over this sample period, are supported by parameter stability tests over the final nine quarters or more of the estimation period which reject the hypothesis of parameter stability. However the interpretation of these tests is made difficult by the limited number of observations available prior to the period over which the hypothesis is tested. Thus in the absence of explicit modelling of the authorities' reaction functions our results are best viewed as typical representations of relationships over the sample period, not as stable equations suitable for policy implementation.

variables taking their predicted values - over the period 1972 Q2-1979 Q3 using equations 12, 14 and 15; [1] this permits a test of the tracking ability of the system. In addition, the same set of equations was used to forecast 1979 Q4-1980 Q4. The test statistics for goodness of fit (Theil's U-statistic and its three decomposed elements) were encouraging for all three endogenous variables,[2] as is also evident from Charts 1-3 which plot the actual and (within-sample) predicted values of the three endogenous variables to 1979 Q3 with forecast values thereafter. The within-sample performance of the model in predicting the exchange rate is particularly encouraging, with the sharp depreciation of the sterling exchange rate during 1976 tracked remarkably well by the model.

63 Some simulation results were also obtained using data for 1981, although the absence of definitive data on the value of F over this period diminishes their reliability. It was assumed that F, the UK's net foreign asset position, increased by £7 billion during 1981, with half this increase occurring in the first quarter of the year. On this basis, the system performed badly after 1980. Although the eurosterling interest rate continues to be tracked closely, the exchange rate is seriously underpredicted - by six pence to the dollar in the first quarter and by a further four pence to the dollar in the second quarter - and this, in turn, leads to the domestic interest rate being overpredicted (since

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[1] Similar results were obtained from the use of equations 12, 13 and 15.

[2] Endogenous variables predicted (dynamically) by the three-equation model 1972 Q2-1979 Q3:

	i_d	i_x	E
Equations 12, 14 and 15:			
Theil's U statistic	0.337	0.332	0.592
UM	0.003	0.001	0.001
US	0.059	0.010	0.127
UC	0.938	0.989	0.872
RMS error (%)	5.057	4.673	2.642

An optimal predictor of an endogenous variable would yield U=UM=US=0, and UC=1. U evaluates the tracking ability of the system in terms of the predicted and actual first differences; a useful 'rule of thumb' is that this statistic should be less than 0.5, although significance tests cannot be applied to this statistic. UM measures the deviation of the average predicted change from the actual predicted change, while US and UC measure the errors due to unequal variation and unequal covariation respectively [see Theil (1966)].

Chart 1

Actual, predicted and forecast values of i_d: 1972 Q2 - 1981 Q3

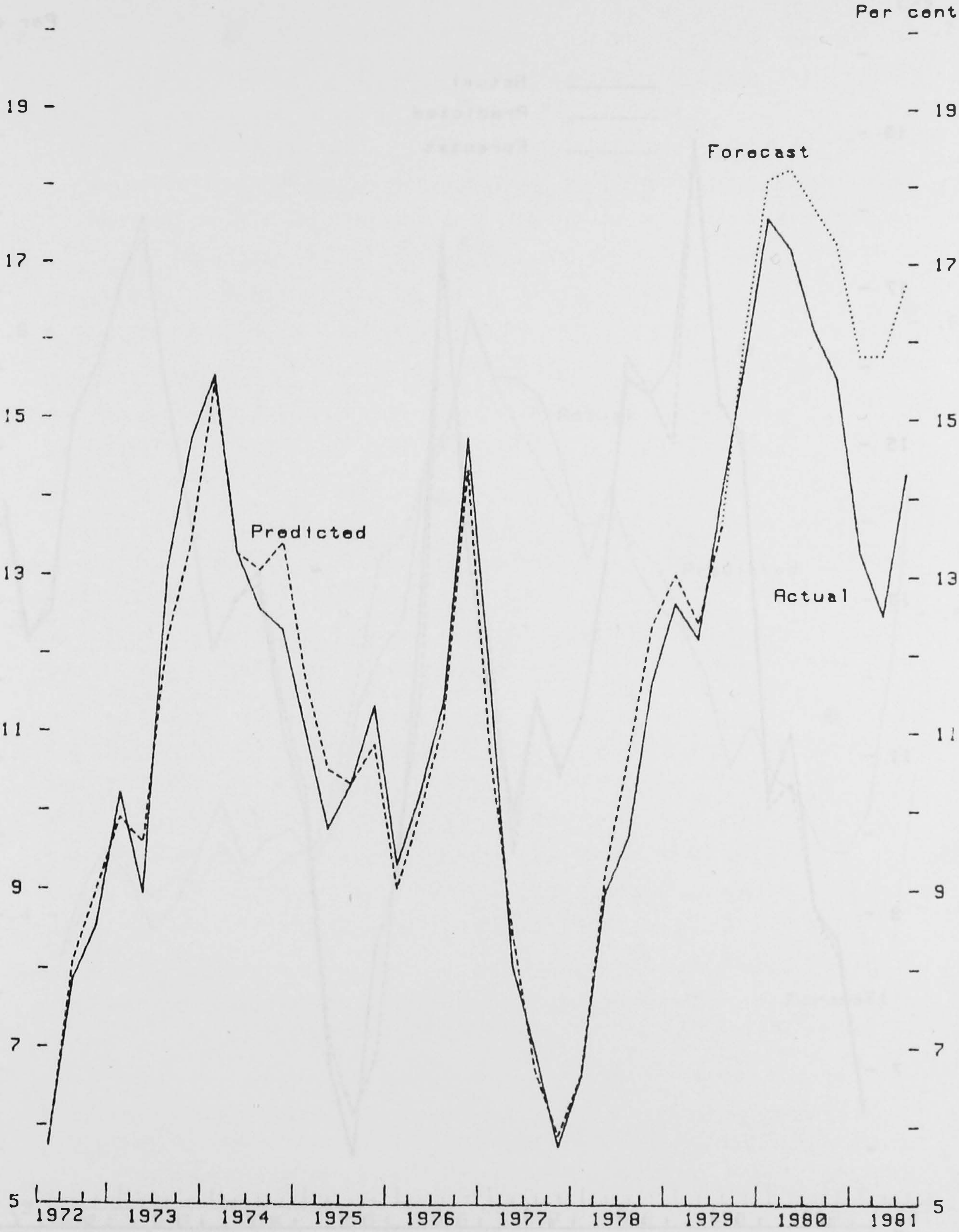


Chart 2

Actual, predicted and forecast values of i_x: 1972 Q2 - 1981 Q3

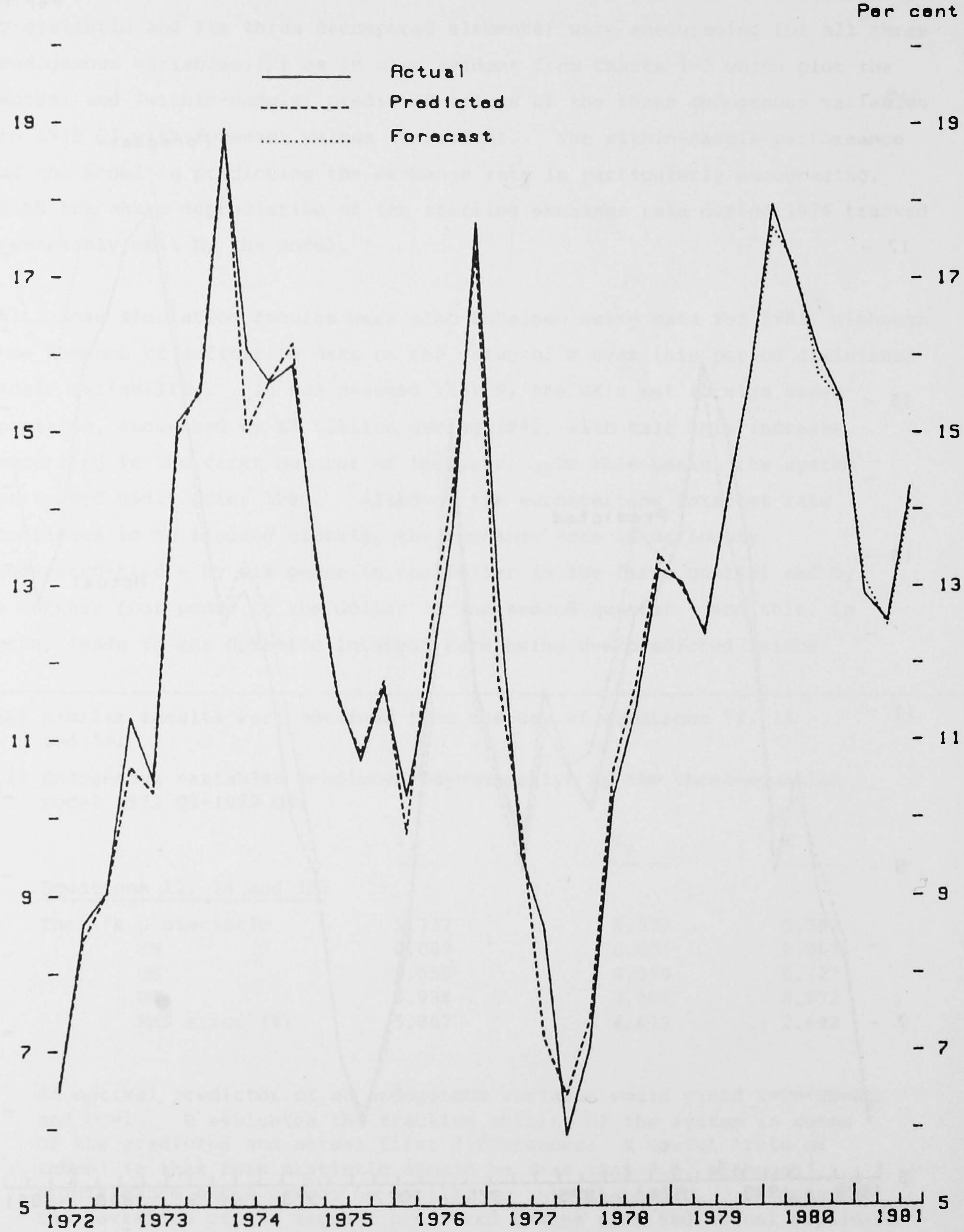
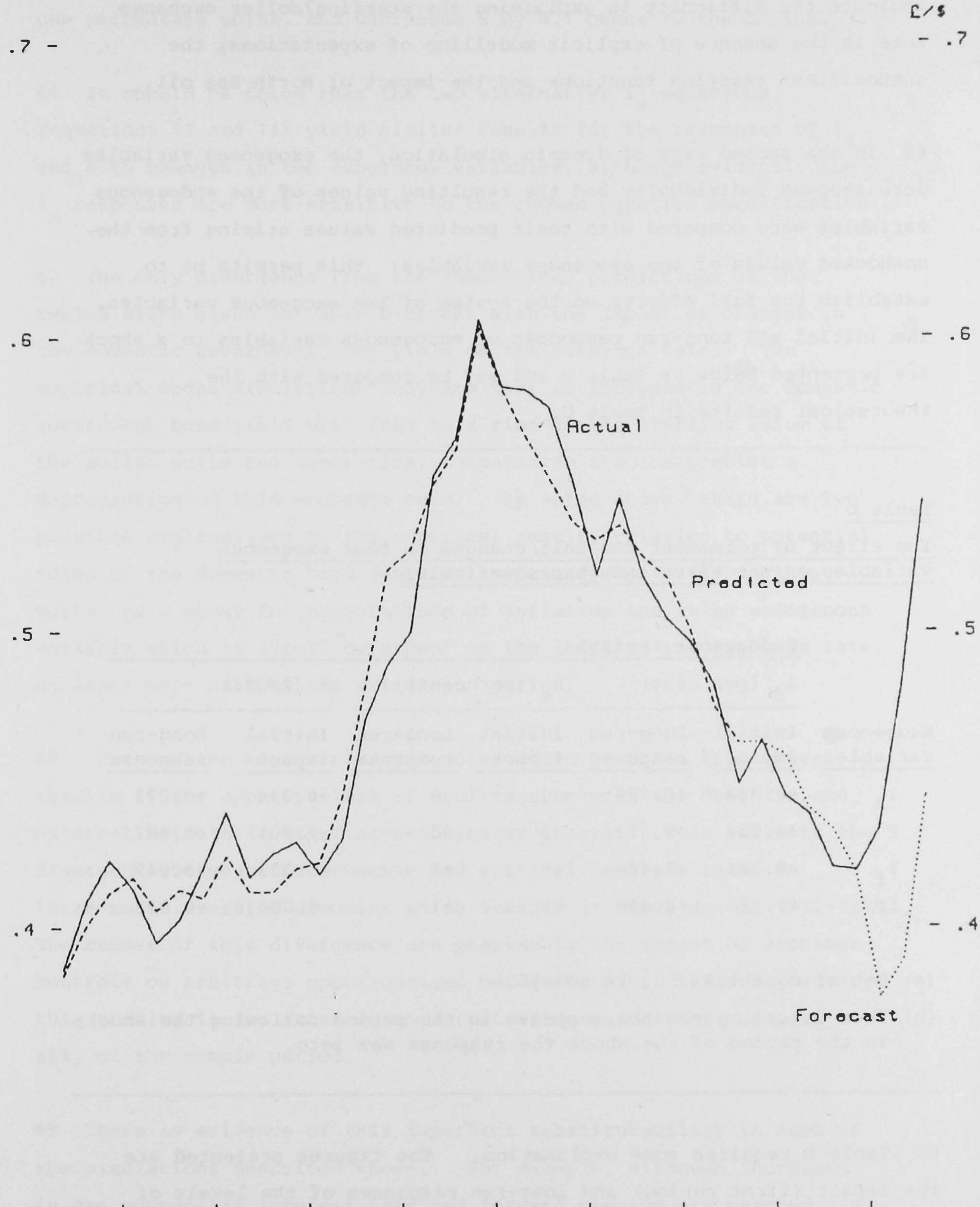


Chart 3

Actual, predicted and forecast values of E: 1972 Q2 - 1981 Q3



E_{t-1} enters equation 12 with a large negative coefficient). The tracking performance of the model over the earlier period, 1972-1980, must be assessed with reference to these results for 1981, which may indicate the difficulty in explaining the sterling/dollar exchange rate in the absence of explicit modelling of expectations, the authorities' reaction functions and the impact of North Sea oil.

64 In the second type of dynamic simulation, the exogenous variables were shocked individually and the resulting values of the endogenous variables were compared with their predicted values arising from the unshocked values of the exogenous variables; this permits us to establish the full effects on the system of the exogenous variables. The initial and long-run responses of endogenous variables to a shock are presented below as Table D and may be compared with the theoretical results in Table C.

Table D

The effect of permanent one unit changes in four exogenous variables on the three endogenous variables(a)

	Endogenous variable					
	i_d (per cent)		i_x (per cent)		E (£/US$)	
Exogenous variables	Initial impact	Long-run response	Initial impact	Long-run response	Initial impact	Long-run response
r_d	+0.704	+0.776	0	0	+0.014	+0.073
F	+0.084	+0.192	0	0	-0.001	-0.001
i_f	+0.226	+0.400	+1	+1	-0.003	-0.047
fp	+0.370	+0.450	+1	+1	-0.006(b)	-0.022

(a) Set of equations 12, 14 and 15.

(b) This figure gives the response in the period following the shock; in the period of the shock the response was zero.

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65 Table D requires some explanation. The figures presented are the impact (first period) and long-run responses of the levels of the endogenous variables to a permanent one unit change in the level of the relevant exogenous variable. Except for F, where the response is to a $1 billion change in the net foreign asset position of the

United Kingdom, the responses are to changes of one percentage point in the exogenous variables. Thus, for example, a permanent one percentage point increase in i_f,[1] the eurodollar interest rate, eventually increases i_d by 0.4 percentage points, increases i_x by one percentage point, and decreases E by 4.7 pence to the dollar.

66 It should be noted that the two alternative i_x equations (equations 13 and 14) yield similar results for the responses of i_d and E to changes in the exogenous variables, although evidently the i_x responses are more sensitive to the chosen equation specification.

67 The only divergence from the theoretical predictions of the twelve signs given in Table D occurs with the impact of changes in the domestic government bond yield on the exchange rate. The empirical model simulations indicate that an increase in the domestic government bond yield will lead to a rise in the sterling value of the dollar while the theoretical comparative statics predict a depreciation of this exchange rate. As noted above, there are two possible explanations of the empirical result, relating to potential roles of the domestic bond yield not modelled explicitly in this work: as a proxy for expectations of inflation and as an endogenous variable which is itself dependent on the level of the exchange rate, at least over part of the estimation period.

68 Perhaps the most striking conclusion to be drawn from these results is the apparent lack of arbitrage between the domestic and external markets in sterling-denominated assets. This reflects the divergence between the domestic and external interest rates on three-month sterling deposits which emerged at times during 1972-1979. The causes of this divergence are presumably the impact of exchange controls on arbitrage opportunities before October 1979 and the very thin trading in the three-month eurosterling market for most, if not all, of the sample period.

69 There is evidence of this imperfect substitutability in each of the simulations described above. For example, although increases in the eurodollar interest rate and forward premium are matched (in

[1] Holding all the other exogenous variables constant.

absolute terms) by increases in the eurosterling interest rate, their impact on the domestic short-term interest rate is considerably less. Predictably in this context the (positive) impact of (positive) shocks to the net foreign asset position of UK residents is greater on the domestic interest rate. The orders of magnitude in this latter case are of interest - a sustained $1 billion increase in the net foreign asset position increases the domestic short-term interest rate by 19 basis points while for the external interest rate the impact is zero.

70 Orders of magnitude are also of some interest with respect to changes in the exchange rate. A permanent one percentage point increase in the five-year bond yield eventually raises the sterling value of the dollar by seven pence to the dollar, while a sustained $1 billion increase in the net foreign asset position lowers this exchange rate by 0.1 pence to the dollar.

71 These results are summarised in Charts 4 and 5,[1] which present the responses over time of i_d and E respectively to permanent changes in the first four exogenous variables presented in Table D. It can be observed that the full long-term effects can take up to twenty periods to materialise, although most of the response has already occurred within ten periods of the shock. It is also evident that the responses of i_d have a tendency to undershoot or overshoot before converging on their long-run values; although this may simply reflect the necessarily limited dynamic specifications of the equations, the time paths are not implausible and provide no reason to reject the model as a representation, albeit limited, of some of the interactions between financial asset markets.

72 In an attempt to utilise additional available information, the reduced form estimation procedure was repeated using monthly data. The drawback in this approach is that monthly data for F and Y are not immediately available, necessitating the creation of monthly series either by interpolation from the quarterly data or by the use of proxy variables. Interpolation introduces spurious frequencies into the monthly series thus created, while the proxies may fail to

[1] Charts 4 and 5 are derived from equations 12, 14 and 15. Similar time paths emerge from equations 12, 13 and 15.

Chart 4

Time path of responses of i_d

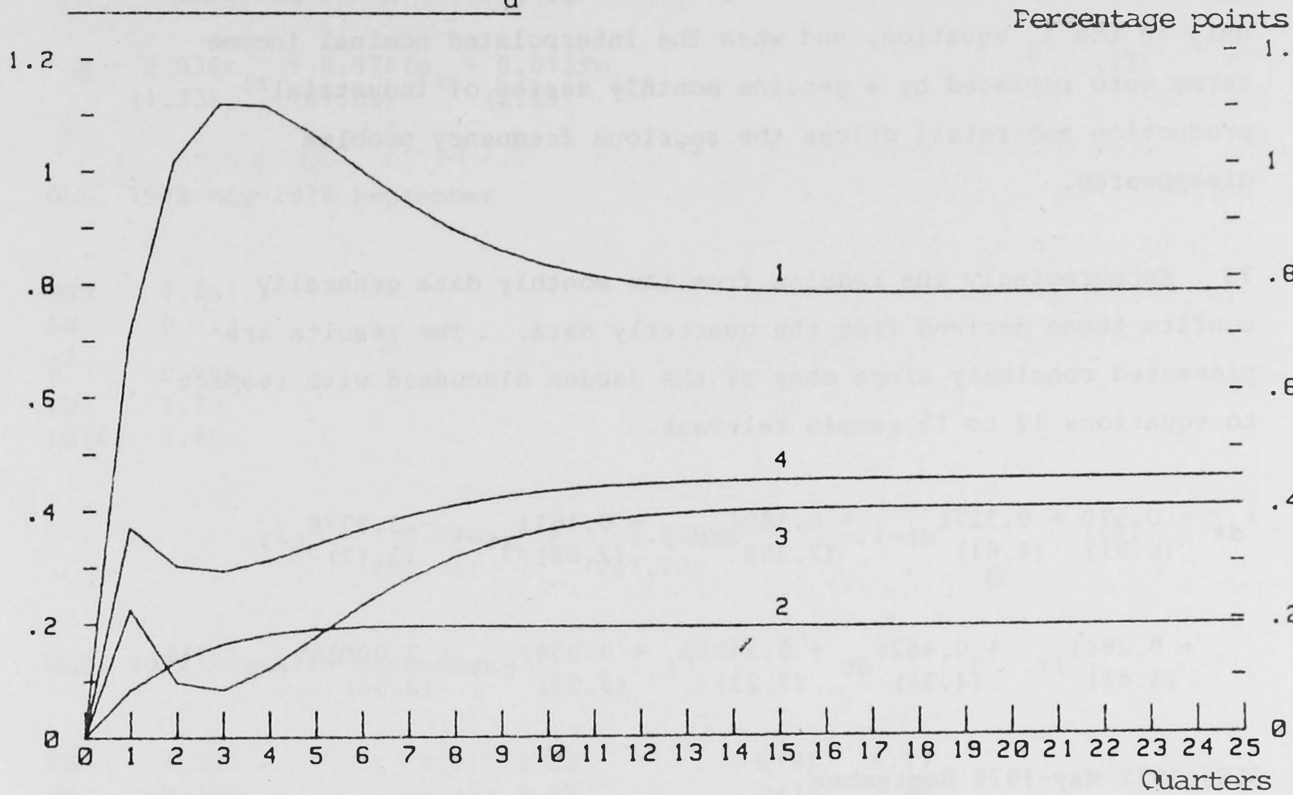
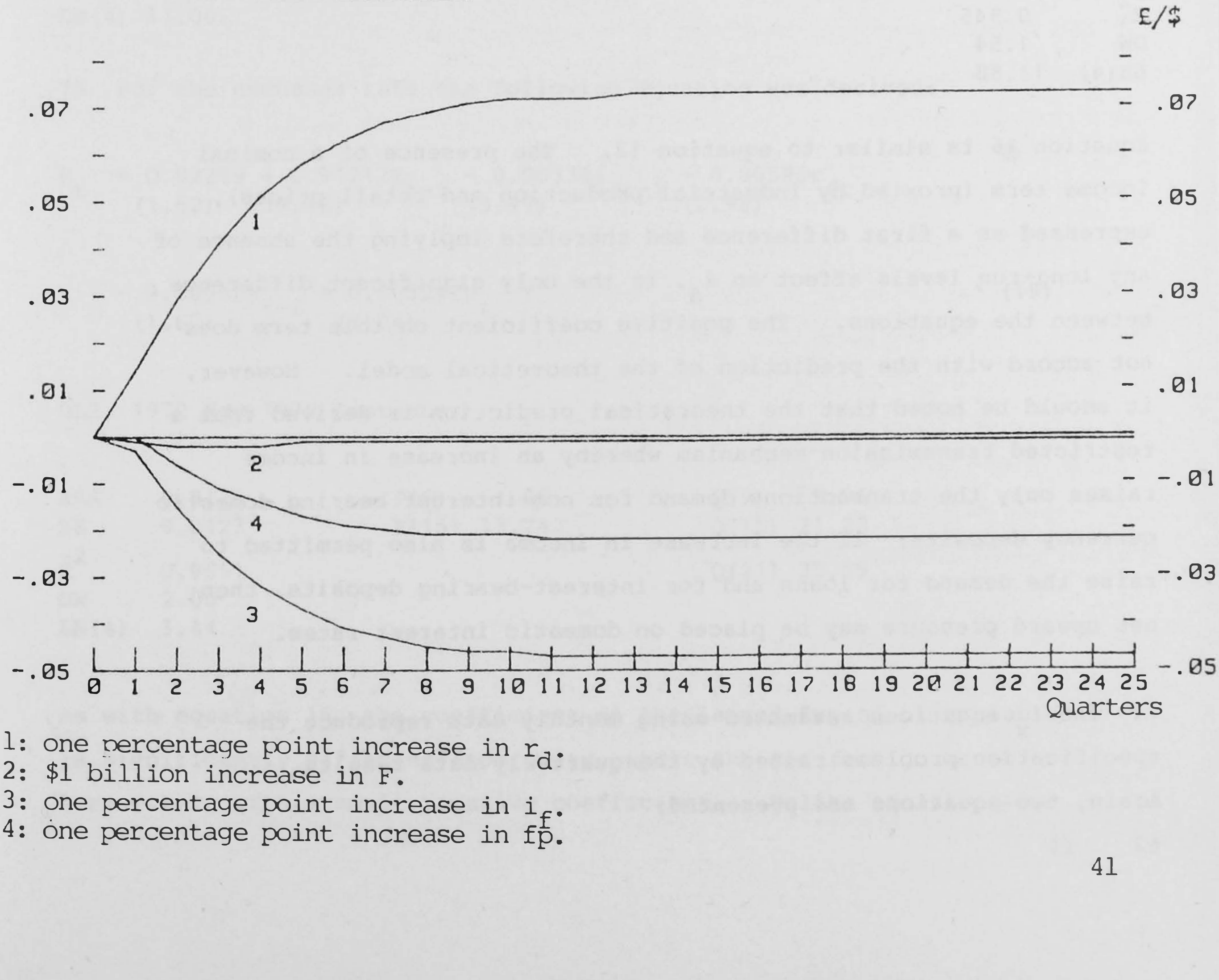


Chart 5

Time path of responses of E



1: one percentage point increase in r_d.
2: $1 billion increase in F.
3: one percentage point increase in i_f.
4: one percentage point increase in fp.

capture the underlying relationships between the original data series. In practice, the interpolation appeared to cause problems only in the i_d equation, and when the interpolated nominal income terms were replaced by a genuine monthly series of industrial production and retail prices the spurious frequency problem disappeared.

73 Encouragingly the results from the monthly data generally confirm those derived from the quarterly data. The results are presented concisely since many of the issues discussed with respect to equations 12 to 15 remain relevant.

$$i_{dt} = \underset{(0.81)}{0.570} + \underset{(4.61)}{0.327}i_{dt-1} + \underset{(2.35)}{0.189}i_{dt-3} - \underset{(2.69)}{0.161}i_{xt-3} - \underset{(2.17)}{2.877}E_{t-3}$$

$$+ \underset{(4.44)}{0.284}i_{ft} + \underset{(4.34)}{0.462}r_{dt} + \underset{(7.23)}{0.340}fp_t + \underset{(3.54)}{0.054}F_{t-3} + \underset{(2.54)}{2.00}\Delta \ln Y_{t-2} \qquad (16)$$

OLS, 1972 May-1979 September

RSS	30.016	P(6)	9.93	Q(9)	24.47
SE	0.616	P(15)	10.57	Q(15)	27.34
$\bar{R}^2$	0.945				
DW	1.54				
LB(4)	11.88				

Equation 16 is similar to equation 12. The presence of a nominal income term (proxied by industrial production and retail prices), expressed as a first difference and therefore implying the absence of any long-run levels effect on i_d, is the only significant difference between the equations. The positive coefficient on this term does not accord with the prediction of the theoretical model. However, it should be noted that the theoretical prediction is derived from a restricted transmission mechanism whereby an increase in income raises only the transactions demand for non-interest bearing domestic currency deposits; if the increase in income is also permitted to raise the demand for loans and for interest-bearing deposits, then net upward pressure may be placed on domestic interest rates.

74 The i_x equations estimated using monthly data reproduce the specification problems raised by the quarterly data results. Again, two equations are presented:

$$i_{xt} = \underset{(0.88)}{-\,0.114} + \underset{(1.47)}{0.018i_{dt-2}} + \underset{(85.20)}{0.965i_{ft}} + \underset{(3.97)}{0.128r_{dt}} - \underset{(2.67)}{0.079r_{dt-1}}$$

$$- \underset{(1.33)}{0.036r_{ft}} + \underset{(87.05)}{0.976fp_t} + \underset{(2.29)}{0.013fp_{t-4}} \qquad (17)$$

OLS, 1972 May-1979 September

RSS	1.231
SE	0.123
$\bar{R}^2$	0.999
DW	1.72
LB(4)	5.40

$$i_{xt} = \underset{(406.04)}{0.994i_{ft}} + \underset{(241.73)}{1.020fp_t} \qquad (18)$$

OLS, 1972 May-1979 September

RSS	1.595	P(6)	3.32	Q(9)	6.77
SE	0.135	P(15)	5.87	Q(15)	7.45
$\bar{R}^2$	0.9999				
DW	1.56				
LB(4)	11.00				

75 For the exchange rate the following equation was derived:

$$E_t = \underset{(1.52)}{0.02289} + \underset{(39.16)}{0.91217E_{t-1}} - \underset{(3.97)}{0.00330i_{dt-1}} + \underset{(2.98)}{0.00596r_{ft}}$$

$$- \underset{(1.62)}{0.00032F_{t-2}} + \underset{(4.04)}{0.00324fp_t} \qquad (19)$$

OLS, 1972 May-1979 September

RSS	0.0126	P(6)	1.06	Q(9)	9.96
SE	0.0123	P(15)	13.74	Q(15)	21.23
$\bar{R}^2$	0.9651			Q(21)	35.59
DW	2.00				
LB(4)	3.44				

As with equation 15, the coefficient on the lagged dependent variable is significantly different from unity, while the net foreign asset term enters with a small negative coefficient. Unlike equation 15, however, it is now the current r_f term rather than r_d which enters with a significant positive coefficient. Again, the theoretical model does not suggest an unambiguous effect here, although one explanation is that the capital outflow consequent on the increase in the foreign currency securities yield induces a rise in the exchange rate, E. The absence of any explicit i_f terms in equation 19 is presumably responsible for the negative coefficient on the lagged domestic short-term interest rate term; the other two equations in the system determine the effect of changes in i_f on the exchange rate as they feed through to i_d and thus to E itself.

76 Dynamic simulation of the equations estimated from monthly data confirms their broad similarity with the results derived from quarterly data which are reported above. Thus equations 16, 18 and 19 together imply that a permanent $1 billion increase in F will raise i_d by 8 basis points within three months and by 17 basis points in the long run, while E falls by 0.1 pence to the dollar in both the short and the long run; a sustained one percentage point increase in the eurodollar interest rate, i_f, increases i_d by 41 basis points after three months (33 in the long run) and lowers E by 0.2 pence and 1.2 pence respectively. Further comparison is provided by the responses to changes in r_d where i_d rises by 66 basis points after three months and 123 basis points in the long run, while E falls by 0.3 pence and 4.6 pence respectively.

77 These results of an econometric application of the theoretical model are encouraging in a number of respects. Each of the exogenous variables, with the exception of nominal GDP, included in the most general formulation of the three-equation system proves to be a significant determinant of at least one of the three endogenous variables in a single equation framework and thus their impact on each of the endogenous variables can be assessed within the framework of model simulations.

78 The net foreign asset position has been included in previous econometric work on the exchange rate; in particular Branson and Halttunen (1979) estimate a specification of the exchange rate equation derived from the Branson (1979) model discussed in Section 2 of this paper. However, it was noted in that section that the

theoretical model presented in this paper is more general than Branson's model and provides for a more complete analysis of monetary policy. Similarly, the econometric work in this paper represents an improvement on the results of Branson and Halttunen, in that it recognises the simultaneity of exchange rate and interest rate determination.

Summary and conclusions

79 This paper presented a model of some of the important links between the internal and external financial markets of a small open economy. A portfolio balance approach was adopted to model the financial sector in which, with a flexible spot exchange rate and with domestic and external assets denominated in the same currency not assumed to be perfect substitutes, the interest rates on domestic currency denominated assets and the spot exchange rate are simultaneously determined. Although the model included a wide range of assets which may be held by resident and non-resident asset holders, a number of simplifying assumptions were made to reduce the number of equations in the model. From these, and the additional assumption that financial assets are strict gross substitutes, comparative statics results were derived which related to the response of interest rates on domestic currency assets and of the exchange rate to changes in exogenous variables such as foreign interest rates. A further application of the model was to discuss the response of several different monetary aggregates to monetary policy changes.

80 The model also proved to be suitable as a basis for empirical work, in which reduced form estimation techniques were used to estimate equations for the three endogenous variables from UK data for the period since the floating of sterling in 1972. These estimated equations constituted a system which, when solved by dynamic simulation techniques, enabled us first to investigate the ability of the system to track the path of the endogenous variables both within the estimation period and beyond it, and second to derive the response of these variables to changes in the exogenous variables. The results of both these investigations were encouraging in that the system tracked reasonably well, at least until 1981, while the theoretical predictions of the model were generally borne out by the empirical results. One interesting aspect of this work was that domestic and external sterling denominated assets were evidently not perfect substitutes over the estimation period, confirming the usefulness of a theoretical model which does not

assume perfect substitutability between these assets, at least when exchange controls are present.

81 Nevertheless, both the theoretical and empirical sections of the paper model only imperfectly two areas of substantial theoretical and econometric difficulty - exchange rate expectations and the authorities' reaction functions. Thus, although this paper represented a departure from most portfolio balance models of international financial markets, in that it assumed neither fixed exchange rates nor perfect substitutability between domestic currency assets, there remain important directions in which future research in this area might usefully proceed.

Appendix 1

Stability and comparative statics

If we write equations 2, 3 and 7 as:

$$M(i_d, i_x, E) = 0$$

$$X(i_d, i_x, E) = 0$$

$$S(i_d, i_x, E) = 0$$

the Jacobian, J, is:

$$\begin{vmatrix} M_{id} & M_{ix} & M_E \\ X_{id} & X_{ix} & X_E \\ S_{id} & S_{ix} & S_E \end{vmatrix}$$

where M_{id} is the partial derivative of M with respect to i_d, etc.

The partial derivatives of M, X and S with respect to both the endogenous and the exogenous variables are signed in Table E, from the information in Table B and the assumption of strict gross substitutability which implies that the partial derivative of the demand for an asset with respect to its own rate of interest is greater in absolute value than its partial derivatives with respect to each of the rates of interest on competing assets. The sign of S_E is shown as negative on the additional assumption that $F > 0$ but it will also be negative when $F < 0$ if F is sufficiently small.

Assume:

$$\frac{di_d}{dt} = K_1 M(i_d, i_x, E) \qquad K_1 < 0$$

$$\frac{di_x}{dt} = K_2 X(i_d, i_x, E) \qquad K_2 < 0$$

$$\frac{dE}{dt} = K_3 S(i_d, i_x, E) \qquad K_3 > 0$$

In other words, the domestic deposit rate is assumed to fall in response to excess demand for domestic deposits, the external deposit rate to fall in response to excess demand for external deposits, while the exchange rate is assumed to rise (the domestic currency to depreciate) in response to an increase in residents' demand for foreign currency securities, a fall in non-residents' demand for domestic currency securities or a fall in the current account surplus (rise in a current account deficit).

Matrix A

$$\begin{bmatrix} \frac{di_d}{dt} \\ \frac{di_x}{dt} \\ \frac{dE}{dt} \end{bmatrix} \simeq \begin{bmatrix} k_1 M_{id} & k_1 M_{ix} & k_1 M_E \\ k_2 X_{id} & k_2 X_{ix} & k_2 X_E \\ k_3 S_{id} & k_3 S_{ix} & k_3 S_E \end{bmatrix} \begin{bmatrix} i_d - i_d^* \\ i_x - i_x^* \\ E - E^* \end{bmatrix}$$

where i_d^*, i_x^*, E^* are the equilibrium values of i_d, i_x, E.

If the system is locally stable, $\frac{di_d}{dt} \to 0$ as $i_d \to i_d^*$, etc; this requires the matrix A to have eigenvalues with negative real parts, which in turn requires the determinant of A to be negative.

Since: $|A| = k_1 k_2 k_3 J$, $|A|<0$ if $J<0$.

Since: $J = M_{id} (X_{ix} S_E - X_E S_{ix}) - M_{ix} (X_{id} S_E - X_E S_{id})$

$+ M_E (X_{id} S_{ix} - X_{ix} S_{id})$

it is a necessary (although not a sufficient) condition for $J<0$ that $(X_{ix} S_E - X_E S_{ix}) < 0$. It can be shown that strict gross substitutability implies that M_{id} and X_{ix} are greater in absolute value than S_{id} and S_{ix} respectively. Hence if $J<0$, S_E must be greater in absolute value than X_E. This is likely when the small open economy is a net creditor ($F>0$) - see Table E.

Assuming stability and hence that $J<0$ and $|S_E|$ is greater than $|X_E|$ (and $|M_E|$) the results listed in Table C are found by total differentiation of equations 2, 3 and 7 and repeated use of Cramer's rule.

For example, consider central bank open-market operations in domestic or foreign currency securities.

If $dR_d^c = dG_d^c$ (and $dr_d = 0$)

$$\frac{di_d}{dR_d^c} = -\frac{1}{J}\,[M_R\,(X_{ix}S_E - X_ES_{ix}) - X_R\,(M_{ix}S_E - M_ES_{ix}) + S_R\,(M_{ix}X_E - M_EX_{ix})] < 0$$

$$\frac{di_x}{dR_d^c} = \frac{1}{J}\,[M_R\,(X_{id}S_E - X_ES_{id}) - X_R\,(M_{id}S_E - M_ES_{id}) + S_R\,(M_{id}X_E - M_EX_{id})] < 0$$

$$\frac{dE}{dR_d^c} = -\frac{1}{J}\,[M_R\,(X_{id}S_{ix} - X_{ix}S_{id}) - X_R\,(M_{id}S_{ix} - M_{ix}S_{id}) + S_R\,(M_{id}X_{ix} - M_{ix}X_{id})] > 0$$

If $dR_d^c = d(ES_f^c)$ (and $dr_d = 0$)

$$\frac{di_d}{dR_d^c} = -\frac{1}{J}\,[M_R\,(X_{ix}S_E - X_ES_{ix}) - X_R\,(M_{ix}S_E - M_ES_{ix}) + (1 + S_R)(M_{ix}X_E - M_EX_{ix})] < 0$$

$$\frac{di_x}{dR_d^c} = \frac{1}{J}\,[M_R\,(X_{id}S_E - X_ES_{id}) - X_R\,(M_{id}S_E - M_ES_{id}) + (1 + S_R)(M_{id}X_E - M_EX_{id})] < 0$$

$$\frac{dE}{dR_d^c} = -\frac{1}{J}\,[M_R\,(X_{id}S_{ix} - X_{ix}S_{id}) - X_R\,(M_{id}S_{ix} - M_{ix}S_{id}) + (1 + S_R)(M_{id}X_{ix} - M_{ix}X_{id})] > 0$$

For changes in r_d:

$$\frac{di_d}{dr_d} = -\frac{1}{J}[M_{rd}(X_{ix}S_E - X_E S_{ix}) - X_{rd}(M_{ix}S_E - M_E S_{ix})$$

$$+ S_{rd}(M_{ix}X_E - M_E X_{ix})] > 0$$

$$\frac{di_x}{dr_d} = \frac{1}{J}[M_{rd}(X_{id}S_E - X_E S_{id}) - X_{rd}(M_{id}S_E - M_E S_{id})$$

$$+ S_{rd}(M_{id}X_E - M_E X_{id})] > 0$$

$$\frac{dE}{dr_d} = -\frac{1}{J}[M_{rd}(X_{id}S_{ix} - S_{id}X_{ix}) - X_{rd}(M_{id}S_{ix} - M_{ix}S_{id})$$

$$+ S_{rd}(M_{id}X_{ix} - M_{ix}X_{id})] < 0$$

Table E

Signs of the partial derivatives

$$M_{i_d} \equiv \overset{+}{\frac{\delta m_d^a}{\delta i_d}} + E\overset{+}{\frac{\delta m_d^f}{\delta i_d}} - \overset{-}{\frac{\delta m_d^b}{\delta i_d}} > 0$$

$$M_{i_x} < 0,\ M_{r_d} < 0,\ M_{i_f} < 0,\ M_{r_f} < 0,\ M_{E^e} < 0$$

$$M_E \equiv \overset{+}{\frac{\delta m_d^a}{\delta E}} + \overset{+}{\frac{\delta m_d^a}{\delta W}}\overset{+}{\frac{dW}{dE}} + \overset{+}{\frac{E\delta m_d^f}{\delta E}} + \overset{+}{m_d^f} - \overset{-}{\frac{\delta m_d^b}{\delta E}} > 0$$

$$M_{Z1} \equiv E\overset{+}{\frac{\delta m_d^f}{\delta Z1}} > 0,\quad M_F \equiv \overset{+}{\frac{\delta m_d^a}{\delta W}}\overset{+}{\frac{dW}{dF}} > 0,\quad M_R \equiv -\overset{-}{\frac{\delta m_d^b}{\delta R}} > 0$$

$$X_{i_d} \equiv \overset{-}{\frac{\delta m_x^a}{\delta i_d}} + E\overset{-}{\frac{\delta m_x^f}{\delta i_d}} - \overset{+}{\frac{\delta m_x^b}{\delta i_d}} < 0$$

$$X_{i_x} > 0,\ X_{r_d} < 0,\ X_{i_f} < 0,\ X_{r_f} < 0,\ X_{E^e} < 0$$

$$X_E \equiv \overset{+}{\frac{\delta m_x^a}{\delta E}} + \overset{+}{\frac{\delta m_x^a}{\delta W}}\overset{+}{\frac{dW}{dE}} + \overset{+}{\frac{E\delta m_x^f}{\delta E}} + \overset{+}{m_x^f} - \overset{-}{\frac{\delta m_x^b}{\delta E}} > 0$$

$$X_{Z2} \equiv E\overset{+}{\frac{\delta m_x^f}{\delta Z2}} > 0,\quad X_F \equiv \overset{+}{\frac{\delta m_x^a}{\delta W}}\overset{+}{\frac{dW}{dF}} > 0,\quad X_R \equiv -\overset{-}{\frac{\delta m_x^b}{\delta R}} > 0$$

$$S_{i_d} \equiv \overset{-}{\frac{\delta s_f^a}{\delta i_d}} + \overset{-}{\frac{\delta s_f^b}{\delta i_d}} - E\left\{\overset{+}{\frac{\delta m_d^f}{\delta i_d}} + \overset{-}{\frac{\delta m_x^f}{\delta i_d}} + \overset{-}{\frac{\delta m_f^f}{\delta i_d}} + \overset{-}{\frac{\delta s_d^f}{\delta i_d}}\right\} < 0$$

$$S_{i_x} < 0,\ S_{r_d} < 0,\ S_{i_f} < 0,\ S_{r_f} < 0,\ S_E e > 0$$

$$S_E \equiv \overset{-}{\frac{\delta s_f^a}{\delta E}} + \overset{+}{\frac{\delta s_f^a}{\delta W}}\ \overset{+}{\frac{dW}{dE}} + \overset{-}{\frac{\delta s_f^b}{\delta E}} - E\left\{\overset{+}{\frac{\delta m_d^f}{\delta E}} + \overset{+}{\frac{\delta m_x^f}{\delta E}} + \overset{-}{\frac{\delta m_f^f}{\delta E}} + \overset{+}{\frac{\delta s_d^f}{\delta E}}\right\}$$

$$- (m_d^f + m_x^f + m_f^f + s_d^f) - F < 0$$

$$\left(\text{since } \frac{dW}{dE} = F \text{ and } 0 < \frac{\delta s_f^a}{\delta W} < 1\right)$$

$$S_Z \equiv - E\left\{\overset{+}{\frac{\delta m_d^f}{\delta Z1}} + \overset{+}{\frac{\delta m_x^f}{\delta Z2}} + \overset{+}{\frac{\delta m_f^f}{\delta Z3}} + \overset{+}{\frac{\delta s_d^f}{\delta Z4}}\right\} < 0$$

$$S_F \equiv \frac{\delta s_f^a}{\delta W}\frac{dW}{dF} - E = \left[\frac{\delta s_f^a}{\delta W} - 1\right] E < 0, \quad S_R = \frac{\delta s_f^b}{\delta R} > 0$$

Appendix 2

Description and published sources of data. Abbreviations used in reporting the econometric results

i_d: three-month UK domestic inter-bank rate (Bank of England Quarterly Bulletin [BEQB])

i_x: three-month eurosterling interest rate (BEQB)

E : spot exchange rate, expressed as pounds sterling per dollar (BEQB)

i_f: three-month eurodollar interest rate (BEQB)

r_d: secondary market gross redemption yield on UK government securities with five years to maturity (Financial Statistics, published by the Organisation for Economic Co-operation and Development [OECD])

r_f: secondary market yield on US government securities with five years to maturity (Financial Statistics, OECD)

fp: three-month forward premium on the dollar against sterling, expressed at an annual percentage rate (BEQB)

F: net foreign asset position of UK residents, $ billions (BEQB)

Y: UK nominal GDP, income definition (Economic Trends, published by the Central Statistical Office [CSO]). Monthly data proxy derived from series for industrial production and retail prices (Economic Trends, CSO)

Quarterly data: all interest rates, the exchange rate and the forward premium are quarterly averages.

Monthly data: all interest rates, the exchange rate and the forward premium are end-month values.

RSS: residual sum of squares

SE: standard error of the equation

DW: Durbin-Watson statistic

LB(r): Ljung-Box statistic, distributed chi-squared (r)

P(m): parameter stability test statistic, distributed chi-squared (m). Equation estimated to m quarters (months) prior to 1980 Q4 (1980 December) and used to forecast over the subsequent m periods.

Q(m); as in P(m), with the equation estimated to m quarters (months) prior to 1979 Q3 (1979 September)

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