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INTEREST RATE AND EXCHANGE RATE DETERMINATION

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by

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I. Introduction

It is well known that modeling exchange rates is difficult. Meese and Rogoff's (1983) results show that a random walk model performs as well as or better than a variety of structural models, where the forecasts from the structural models are based on the actual values of the future explanatory variables. Because of these and other results, the view has become fairly widespread that structural models of exchange rates are not very good. There is, however, somewhat of a dichotomy in the literature between those who deal with small models, where the focus is almost exclusively on exchange rates, and those who deal with large macroeconometric models, where exchange rates make up only a small subset of the endogenous variables. One might have thought, for example, that in a survey like Levich's (1985) both types of models would be considered, but the large models are given only one footnote (fn. 19, p. 1001). It may be that exchange rate determination within the context of large models has not been given a sufficient hearing.

Exchange rate and interest rate equations are estimated and analyzed for 17 countries in this paper. This study is part of a larger project of constructing a multicountry econometric model. One of the aims of this paper is to see if the exchange rate equations that are part of my multicountry model also suffer from the Meese and Rogoff criticism. The results show that the view that structural exchange rate models are not very

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good may be too pessimistic.

The theory upon which the multicountry econometric model is based is outlined in Section II. The exchange rate and interest rate equations are estimated in Section III and tested in Section IV.

II. The Theoretical Model

The main features of my multicountry econometric model can be seen by analyzing a two country model.[2] Capital letters will denote variables for country 1, lower case letters will denote variables for country 2, and an asterisk (*) on a variable will denote the other country's holdings or purchase of the variable. There are three sectors per country: private non financial (p), financial (b), and government (g). The private non financial sector includes both households and firms. It will be called the "private sector." Members of the financial sector will be called "banks." Each country specializes in the production of one good (X,x). Each country has its own money (M,m) and its own bond (B,b). Only the private sector of the given country holds the money of the country. The bonds are one-period securities. If a sector is a debtor with respect to a bond (i.e., a supplier of the bond), then the value of B or b for this sector is negative. The interest rate on B is R and on b is r. The price of X is P and of x is p. e is the price of country 2's currency in terms of country 1's currency, so that, for example, and increase in e is a depreciation of country 1's

[2]The following model is similar to the model in Fair (1979), although the present model is simpler. In the earlier model, household and firm sectors were considered separately, a labor market was introduced, and each country was allowed to hold the other country's money. It is unnecessary to introduce these features into the present model for purposes of this paper.

currency. The government of each country holds a positive amount of the international reserve (Q,q), which is denominated in the units of country 1's currency. The government of a country does not hold the bond of the other country and does not buy the good of the other country. Y denotes real GNP of country 1, and y denotes real GNP of country 2.

There are 17 equations per country and one redundant equation. The equations for country 1 are as follows. (The sign above an explanatory variable indicates the expected effect of the variable on the left hand side variable.) The demands for the two goods by the private sector of country 1 are

$$(1) \quad X_p = f_1(\overset{-}{P}, \overset{+}{e \cdot p}, \overset{-}{R}, \overset{+}{Y}) \; ,$$

$$(2) \quad x^*_p = f_2(\overset{+}{P}, \overset{-}{e \cdot p}, \overset{-}{R}, \overset{+}{Y}) \; .$$

The demands are a function of the two prices, the interest rate, and income as measured by GNP. X_p is the purchase of country 1's good by the private sector of country 1, and x^*_p is the purchase of country 2's good by the private sector of country 1. The domestic price level is assumed to be a function of demand pressure as measured by Y and of the level of import prices, $e \cdot p$:

$$(3) \quad P = f_3(\overset{+}{Y}, \overset{+}{e \cdot p}) \; .$$

There is assumed to be no inventory investment, so that production is equal to sales:

$$(4) \quad Y = X_p + X_g + X^*_p \; ,$$

where X_g is the purchase of country 1's good by its government and X^*_p is the purchase of country 1's good by country 2. Taxes paid to the government are

(5) $T_p = TX \cdot Y$,

where TX is the tax rate.[3]

The demand for money is assumed to be a function of the interest rate and income:

(6) $M_p/P = f_6(\overset{-}{R}, \overset{+}{Y})$.

Borrowing by the banks from the monetary authority (BO) is assumed to be a function of R and of the discount rate RD:

(7) $BO = f_7(\overset{+}{R}, \overset{-}{RD})$.

Since the private sector is assumed to be the only sector holding money,

(8) $M_b = M_p$,

where M_b is the money held in banks. Equation (8) simply says that all money is held in banks. Banks are assumed to hold no excess reserves, so that

(9) $BR = RR \cdot M_b$,

where BR is the level of bank reserves and RR is the reserve requirement

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[3]There are some differences between the above model and my multicountry econometric model. In the econometric model, separate consumption and fixed investment equations are estimated (consumption and investment including both domestic and foreign goods), an equation determining inventory investment is estimated, and in the GNP definition GNP is equal to consumption plus fixed investment plus inventory investment plus government spending plus exports minus imports. Imports are subtracted because they are in consumption and investment. Again, for purposes of this paper it is unnecessary to add these features to the theoretical model.

rate.

The expected (one-period) return on the bond of country 2 is $(e^e_{+1}/e)(1 + r) - 1$, where e^e_{+1} is the expected exchange rate for the next period based on information available in the current period and r is the interest rate on the bond of country 2. The demand for country 2's bond is assumed to be a function of R and of the expected return on country 2's bond:

$$(10)\quad b^*_p = f_{10}[\overset{+}{R},\ (e^e_{+1}/e)(\overset{-}{1} + r) - 1] \quad .$$

b^*_p is the amount of country 2's bond held by country 1. If capital mobility is high, large changes in b^*_p will result from small changes in the difference between R and the expected return on country 2's bond. If capital mobility is perfect, R is always equal to the expected return on country 2's bond, and equation (10) drops out. It is assumed here that capital mobility is not perfect.

The next three equations determine the financial saving of each sector:

$$(11)\quad S_p = P \cdot X_g + P \cdot X^*_p - e \cdot p \cdot x^*_p - T_p + R \cdot B_p + e \cdot r \cdot b^*_p \quad ,$$

$$(12)\quad S_b = R \cdot B_b - RD \cdot BO \quad ,$$

$$(13)\quad S_g = T_p - P \cdot X_g + R \cdot B_g + RD \cdot BO \quad .$$

Equation (11) states that the saving of the private sector is equal to revenue from the sale of goods to the government plus export revenue minus import costs minus taxes paid plus interest received (or minus interest paid) on the holdings of country 1's bond and plus interest received on the holdings of country 2's bond. If the private sector is a net debtor with respect to the bond of country 1, then B_p is negative and $R \cdot B_p$ measures interest payments. Remember that the private sector (p) is a combination of households and firms, and so transactions between households and firms net out of equation (11). Equation (12) states that the saving of banks is equal to interest revenue on bond holdings (assuming B_b is positive) minus interest payments on borrowings from the monetary authority. Equation (13) determines the government's surplus or deficit. It states that the saving of the government is equal to tax revenue minus expenditures on goods minus interest costs (assuming B_g is negative) and plus interest received on loans to banks.

The next three equations are the budget constraints facing each sector:

$$(14) \quad 0 = S_p - \Delta M_p - \Delta B_p - e \cdot \Delta b_p^* ,$$

$$(15) \quad 0 = S_b - \Delta B_b + \Delta M_b - \Delta(BR - BO) ,$$

$$(16) \quad 0 = S_g - \Delta B_g + \Delta(BR - BO) - \Delta Q .$$

Equation (14) states that any nonzero value of saving of the private sector must result in the change in its money or bond holdings. Equation (15) states that any nonzero value of saving of the financial sector must result in the change in bond holdings, money deposits (which are a liability to banks), or nonborrowed reserves. Equation (16) states that any nonzero value of saving of the government must result in the change in bond holdings, nonborrowed reserves (which are a liability to the government), or international reserve holdings.

There is also a constraint across all sectors, which says that someone's asset is someone else's liability with respect to the bond of country 1:

$$(17) \quad 0 = B_p + B_b + B_g + B_p^* .$$

These same 17 equations are assumed to hold for country 2, with lower case and upper case letters reversed except for Q and with 1/e replacing e. Q is replaced by q/e. (Remember that Q and q are in the units of country 1's currency.) The last equation of the model is

$$(35) \quad 0 = \Delta Q + \Delta q \ ,$$

which says that the change in reserves across countries is zero. Equation (35) is implied by equations (11) - (17) and the equivalent equations for country 2, and so it is redundant. There are thus 34 independent equations in the model.

In the present analysis the following variables for country 1 are always taken to be exogenous: X_g, government purchases of goods; TX, the tax rate; RD, the discount rate; and RR, the reserve requirement rate. The same is true for country 2. Not counting these variables, there are 38 variables in the model: B_b, B_g, B_p, B_p^*, BO, BR, M_b, M_p, P, Q, R, S_b, S_g, S_p, T_p, X_p, X_p^*, Y, these same 18 variables for country 2, e, and e_{+1}^e. In order to close the model one needs to make an assumption about how e_{+1}^e is determined and to take three other variables as exogenous.

Assume for now that exchange rate expectations are static in the sense that $e_{+1}^e = e$ always. The model can then be closed by taking B_g, b_g, and Q as exogenous. These are the three main tools of the monetary authorities. Instead of taking the three tools to be exogenous, however, one can assume that the monetary authorities use the tools to manipulate R, r, and e. (Remember that it is assumed here that capital mobility is not perfect, which implies that the monetary authorities can in principle achieve any target values of R, r, and e that they want.) Another way of putting this is that one can take R, r, and e to be exogenous in the model if B_g, b_g, and Q are taken to be endogenous. The solution values of B_g, b_g, and Q will be whatever is needed to have the exogenously chosen values of R, r, and e be met.

The estimated exchange rate and interest rate equations in my multicountry model are based on the assumption that the monetary authorities manipulate R, r, and e. Exchange rate and interest rate "reaction functions" are estimated, where the explanatory variables in these equations are assumed to be variables that affect the monetary authorities' decisions. The key question, of course, is what variables affect the monetary authorities' decisions. If capital mobility is high, it will take large changes in the three tools to achieve values of R, r, and e much different from what the market would otherwise achieve. Since the monetary authorities are likely to want to avoid large changes in the tools, they are likely to be sensitive to and influenced by market forces. In short, they are likely to take market forces into account in setting their target values of R, r, and e. Therefore, one needs to know the market forces that affect R, r, and e in the model in order to guide the choice of explanatory variables in the reaction functions.

In order to examine the market forces on R, r, and e in the model, a "simulation" version has been analyzed. Particular functional forms and coefficients have been chosen for equations (1), (2), (3), (6), (7), and (10) and the equivalent equations for country 2. The twelve chosen equations for the simulation version are presented in the Appendix along with the base values of all the variables. The simulation model can be solved using the Gauss-Seidel algorithm. A given set of "base" values was chosen for the exogenous variables, and the model was solved for the endogenous variables. These solution values of the endogenous variables are then their base values. The model is analyzed by changing something in it and solving it again. The difference between the new solution value for an endogenous variable and the old solution value (i.e., the base value) is the amount by which the change has affected the endogenous variable.

In order to help in understanding the properties of the model, it will be useful to consider two equations that can be derived from the others. Let S denote the financial saving of country 1, which is the sum of the saving of the three sectors: $S = S_p + S_b + S_g$. S is the balance of payments on current account of country 1. Summing equations (14)-(16) and using (17) yields:

$$(36)\quad 0 = S + \Delta B_p^* - e \cdot \Delta b_p^* - \Delta Q \ .$$

This equation simply says that any nonzero value of saving of country 1 must result in the change in at least one of the following three: country 2's holdings of country 1's bond, country 1's holding of country 2's bond, and country 1's holding of the international reserve. The derived equation for S can be obtained by summing equations (11)-(13) and using (17):

$$(37)\quad S = P \cdot X_p^* - e \cdot p \cdot x_p^* - R \cdot B_p^* + e \cdot r \cdot b_p^* \ .$$

This equation says that the saving of country 1 is equal to export revenue minus import costs minus interest paid to country 2 plus interest received from country 2.

The following experiments give an idea of the market forces affecting

R, r, and e in the model.[4] Unless otherwise noted, the experiments are based on the assumption that $e^e_{+1} = e$. This means from equation (10) and the equivalent equation for country 2 that b^*_p and B^*_p are simply a function of R and r. In all but the last experiment e is endogenous and Q is exogenous. Taking Q to be exogenous means that the monetary authorities are not manipulating e. This is a way of examining the market forces on e. The solution value of e for each experiment is the value that would pertain if the monetary authorities did not intervene at all in the foreign exchange market in response to whatever change was made for the experiment. B_g and b_g are always endogenous for the experiments because all the experiments either have R and r exogenous or M_b and m_b exogenous. In other words, it is always assumed that the monetary authorities either keep interest rates or money supplies unchanged in response to whatever change was made for the experiment. When R and r are exogenous, M_b and m_b are endogenous, and vice versa. All shocks in the experiments are for country 1.

Experiment 1: R exogenous and lowered, r exogenous and unchanged.

For this experiment the interest rate for country 1 was lowered (from its base value) and the interest rate for country 2 was assumed to remain unchanged. This change resulted in a depreciation of country 1's currency. The fall in R relative to r led to an increase in the demand for the bond of country 2 by country 1 (b^*_p increased) and a decrease in the demand for the bond of country 1 by country 2 (B^*_p decreased). From equation (36) it can be

[4]Numerical results from the experiments are not reported in the following discussion. The numerical magnitudes mean very little; the simulation model is simply meant to be used to help in understanding the qualitative effects on the various variables. See the Appendix for further discussion of this.

seen that this must result in an increase in S, country 1's balance of payments, since Q is exogenous and unchanged. S is increased by increasing country 1's exports and decreasing its imports -- equation (37) -- which is accomplished by a depreciation. Another way of looking at this is that the fall in R relative to r led to a decreased demand for country 1's currency because of the capital outflow, which resulted in a depreciation of country 1's currency. GNP for country 1 increased because of the lower interest rate and the depreciation, and the demand for money increased because of the lower interest rate and the higher level of income. The monetary authority of country 1 bought bonds to achieve the reduction in R (B_g increased).

Experiments with alternative coefficients in the equations explaining b_p^* and B_p^* -- equation (10) and the equivalent equation for country 2 -- showed that the more sensitive are the demands for the foreign bonds to the interest rate differential, the larger is the depreciation of the exchange rate and the larger is the increase in B_g for the same drop in R. In other words, the higher is the degree of capital mobility, the larger is the size of open market operations that is needed to achieve a given target value of the interest rate.

Remember that the above experiment is for the case in which exchange rate expectations are static, i.e. where $e_{+1}^e = e$. If instead expectations are formed in such a way that e_{+1}^e turns out to be less than e, which means that the exchange rate is expected to appreciate in the next period (i.e., reverse at least some of the depreciation in the current period), then the depreciation in the current period is less. This is because if e_{+1}^e is less than e, the expected return on country 2's bond falls. The differential between R and the expected return on country 2's bond thus falls less as a result of the decrease in R, which leads to a smaller increase in b_p^* and a smaller decrease in B_p^*. There is thus less downward pressure on country 1's currency and thus a smaller depreciation. If expectations are formed in such a way that e_{+1}^e turns out to be greater than e, which means that the exchange rate is expected to depreciate further in the next period, there is more of a depreciation in the current period. The expected return on country 2's bond rises, which leads to greater downward pressure on country 1's exchange rate.

Experiment 2: M_b exogenous and increased, m_b exogenous and unchanged.

For this experiment the monetary authorities are assumed to target the money supplies (M_b and m_b), and the money supply of country 1 was increased. The increase in M_b led to a decrease in R, both absolutely and relative to r, which led to a depreciation of country 1's currency. The results of this experiment are similar to those of experiment 1. The monetary authority of country 1 bought bonds to increase the money supply (B_g increased). Country 1's GNP increased as a result of the depreciation and the fall in R. Note that the effect of a change in the money supply on the exchange rate works through the change in relative interest rates. The interest rate of country 1 falls relative to that of country 2, which decreases the demand for country 1's bond and increases the demand for country 2's bond, which leads to a depreciation of country 1's exchange rate.

Experiment 3: Positive price shock, R and r exogenous and unchanged.

For this experiment the price equation for country 1 was shocked positively. The monetary authorities were assumed to respond to this by keeping interest rates unchanged. The positive price shock resulted in a depreciation of country 1's currency. A positive price shock leads to a decrease in the demand for exports and an increase in the demand for imports, which puts downward pressure on S. If, however, interest rates are unchanged, b_p^* and B_p^* do not change, which means from equation (36) that S cannot change. Therefore, a depreciation must take place to decrease export demand and increase import demand enough to offset the effects of the price shock. Put another way, a positive price shock leads to a decreased demand for country 1's currency because of the increased import demand and the decreased export demand, which puts downward pressure on the price of the currency.

Experiment 4: Positive price shock, M_b and m_b exogenous and unchanged.

This experiment is the same as experiment 3 except that the money supplies are kept unchanged rather than the interest rates. The positive price shock with the money supplies unchanged led to an increase in R, both absolutely and relative to r. Even though R increased relative to r, country 1's currency depreciated. The negative effects of the price shock (though decreased export demand and increased import demand) offset the positive effects of the interest rate changes.

Experiment 5: Positive import demand shock, M_b and m_b exogenous and unchanged.

For this experiment the import demand equation of country 1 was shocked positively. The increased demand for imports led to a depreciation of country 1's currency, since there was an increased demand for country 2's currency. The depreciation led to an increase in Y and P, which with an unchanged money supply, led to an increase in R. R also increased relative to r, which increased B_p^* and decreased b_p^*. The balance of payments, S, worsened. It may at first glance seem odd that a positive import shock would lead to an increase in Y, but remember that the shock does not correspond to any shock to the demand for the domestic good. The experiment is not a substitution away from the domestic good to the imported good, but merely an increase in demand for the imported good. The latter results in an increase in Y because of the stimulus from the depreciation.

Experiment 6: R exogenous and lowered, r exogenous and unchanged, e exogenous and unchanged.

This experiment is the same as experiment 1 except that e rather than Q is exogenous. In this case the monetary authorities choose B_g, b_g, and Q so as to lower R and keep r and e unchanged. One of the key differences between the results for this experiment and the results for experiment 1 is that the balance of payments, S, decreases rather than increases. In experiment 1 S had to increase because of the increase in the demand for country 2's bond by country 1 and the decrease in the demand for country 1's bond by country 2. In this case S must increase because Q is exogenous -- equation (36). The increase in S is accomplished by a depreciation. In the present experiment there is still an increase in the demand for country 2's bond and a decrease in the demand for country 1's bond -- because R falls relative to r -- but S does not necessarily have to increase because Q can change. The net effect is that S decreases (and thus Q decreases). The reason for the decrease is fairly simple. The decrease in R is an expansionary action in country 1, and among other things it increases the country's demand for imports. This then worsens the balance of payments. There is no offsetting effect from a depreciation of the currency to reverse this movement.

These six experiments should give one a fairly good idea of the properties of the model. Of main concern here are the effects of the various changes on the domestic interest rate and the exchange rate. The following is a summary of these effects in the model (experiment 6 is not included because both R and e are exogenous in it):

	Effect on	
Experiment	Domestic Interest Rate	Exchange Rate
1. Interest rate lowered	--	Depreciation
2. Money supply raised	Lowered	Depreciation
3. Positive price shock; interest rates unchanged	--	Depreciation
4. Positive price shock; money supply unchanged	Raised	Depreciation
5. Positive import shock; money supply unchanged	Raised	Depreciation

III. The Estimated Equations

The above theoretical model can be used to guide the choice of explanatory variables for the interest rate and exchange rate reaction functions. Before doing this, however, it will help put the present approach in perspective to consider an alternative approach that could in principle be used to estimate the model. If all the equations in the theoretical model that are not identities were estimated, one could solve the model for R, r, and e by taking B_g, b_g, and Q as exogenous. R, r, and e would thus be determined without having to estimate any direct equations for them. In doing this, however, one would be making the rather extreme assumption that the monetary authorities' choices of B_g, b_g, and Q are never influenced by the state of the economy, i.e. are always exogenous.

If one believes that monetary authorities intervene at least somewhat, there are essentially two options open. One is to estimate equations with B_g, b_g, and Q on the left hand side, and the other is to estimate equations with R, r, and e on the left hand side. If the first option is followed, the B_g, b_g, and Q equations are added to the model and the model is solved for R, r, and e. If the second option is followed, the R, r, and e equations are added to the model and the model is solved for B_g, b_g, and Q. The first option is awkward because one does not typically think of the monetary authorities having target values of the instruments themselves. It is more natural to think of them having target values of interest rates (or money supplies[5]) and exchange rates, and this is the assumption made here.

There is also a practical reason for taking the present approach. If B_g, b_g, and Q are taken to be exogenous or equations estimated for them, the entire model must be estimated in order to solve for R, r, and e. In

[5]It is in the spirit of the present approach to estimate money supply reaction functions rather than interest rate reaction functions. In either case B_g is endogenous. No attempt was made in this study to try to estimate money supply reaction functions. This study is based on the implicit assumption that interest rate reaction functions provide a better approximation of the way monetary authorities behave than do money supply reaction functions.

practice it is very difficult to estimate equations like (10), which determine the bilateral demands for securities. One of the main problems is that data on bilateral holdings of securities either do not exist or are not very good. If equations for interest rates and exchange rates are estimated instead, one can avoid estimating equations like (10) in order to determine interest rates and exchange rates if one is willing to give up determining B_g, b_g, and Q. This is what I have done in my multicountry model. For many applications one can get by without knowing the amounts of government bonds outstanding and government reserve holdings. One can simply keep in mind that the values of these variables are whatever is needed to have the interest rate and exchange rate values be met. The estimated equations will now be discussed.

Interest Rate Equations

Estimated interest rate equations are presented in Table 1 for 17 countries. The same set of explanatory variables was tried for each country. The general form of the interest rate equation is

$$(38)\quad R = f_{38}(\overset{+}{\dot{P}_{-1}}, \overset{+}{D}, \overset{-}{A_{-1}}, \overset{+}{A_{-2}}, \overset{+}{\dot{M}_{-1}}, \overset{+}{R_{US}}, \overset{+}{RG_E}, \overset{+}{R_{-1}}) ,$$

where R is the country's short term interest rate, $\dot{P}$ is the rate of inflation, D is a measure of demand pressure, A is the real net asset position of the country relative to the rest of the world as a percent of a measure of full employment GNP of the country, $\dot{M}$ is the rate of growth of the per capital money supply, R_{US} is the U.S. short term interest rate, and R_{GE} is the German short term interest rate. This choice of explanatory variables will now be explained.

TABLE 1. Estimate of the interest rate equations. Dependent variable is R.

	First $\hat{\rho}$	Second $\hat{\rho}$	$\dot{P}_{-1}$	D	A_{-1}	A_{-2}	$\dot{M}_{-1}$	R_{US}	R_{GE}	R_{-1}	DW	SE	R^2	Sample
Canada	.40	.40	.027	-7.3	-74.1[a]	70.9[b]	.004	.77	—	.42	1.87	.697	.966	711-854
	(3.09)	(3.09)	(0.69)	(0.94)	(3.37)	(3.45)	(0.71)	(10.21)		(6.19)				
Japan	.20	0	.031	-3.2	-50.2	60.7	.006	-.01	—	.81	1.64	.661	.929	722-854
	(1.36)		(1.24)	(0.64)	(4.24)	(4.79)	(0.72)	(0.14)		(14.63)				
Australia	.12	0	-.024	37.0	-6.7	5.5	-.032	.06	—	.96	1.81	.895	.908	722-854
	(0.74)		(0.82)	(4.11)	(0.67)	(0.57)	(2.61)	(1.27)		(12.02)				
Germany	-.29	0	.050	21.5	-13.7	8.6	-.015	.16	—	.68	2.48	.639	.937	741-854
	(1.78)		(1.43)	(2.14)	(1.26)	(0.88)	(0.84)	(2.28)		(10.21)				
Austria[c]	.06	0	.018	1.7	-9.3	11.4	.003	.16	.00	.71	1.93	.460	.823	722-861
	(0.35)		(1.50)	(0.56)	(2.04)	(2.37)	(0.56)	(3.06)	(0.05)	(10.13)				
Belgium	.14	0	-.023	13.9	-16.9[a]	13.7[b]	-.036	.20	.02	.62	1.84	1.182	.844	722-844
	(0.66)		(0.46)	(1.52)	(1.25)	(1.13)	(1.44)	(1.50)	(0.16)	(7.32)				
Denmark	-.38	-.38	.222	15.6	-89.8	83.8	-.042	.05	.04	.55	2.25	1.990	.762	722-844
	(2.69)	(2.69)	(3.44)	(1.55)	(4.79)	(4.61)	(2.37)	(0.30)	(0.31)	(6.33)				
France	.22	0	-.043	21.2	-54.5	35.7	-.043	.31	.30	.54	1.60	.855	.919	722-854
	(1.25)		(0.93)	(2.50)	(3.00)	(2.27)	(0.39)	(4.23)	(3.53)	(5.78)				
Italy	.32	0	-.032	19.1	-55.1	52.7	-.032	.34	-.32	.78	1.55	1.125	.938	722-853
	(1.46)		(0.97)	(1.69)	(4.87)	(4.58)	(2.89)	(3.23)	(2.34)	(7.57)				
Netherlands	-.19	0	-.022	16.3	-6.3	13.0	-.041	.34	.34	.38	2.11	1.571	.774	722-844
	(0.88)		(0.24)	(2.60)	(0.43)	(0.90)	(2.24)	(2.14)	(2.11)	(3.94)				
Norway	-.23	0	-.011	-13.7	-2.4[a]	1.8[b]	.004	.23	.02	.65	2.18	1.513	.727	722-844
	(1.29)		(0.21)	(1.37)	(0.36)	(0.26)	(0.55)	(1.23)	(0.15)	(6.75)				
Sweden	.16	0	.060	29.1	-4.6[a]	3.0[b]	NA	.06	.07	.71	1.77	1.085	.909	722-853
	(0.83)		(1.73)	(2.73)	(0.45)	(0.30)		(0.59)	(0.79)	(7.25)				
Switzerland	.43	0	-.005	5.6	-12.1	9.3	-.006	.21	-.03	.54	1.35	.556	.900	722-843
	(1.91)		(0.25)	(1.25)	(2.20)	(1.76)	(0.93)	(2.97)	(0.43)	(5.82)				
U.K.	.23	0	.004	17.5	-15.9[a]	18.6[b]	.006	.33	-.14	.81	1.65	1.091	.819	722-861
	(0.96)		(0.15)	(2.15)	(1.20)	(1.48)	(0.35)	(3.34)	(1.38)	(8.91)				
Finland	.30	0	-.001	6.4	-7.7	7.6	-.003	.10	-.06	.91	1.56	.746	.918	722-854
	(1.93)		(0.06)	(0.65)	(1.53)	(1.33)	(0.67)	(1.54)	(0.93)	(19.54)				
Ireland	.24	0	.009	13.4	-4.1	3.2	-.019	.33	-.09	.65	1.69	1.408	.848	722-844
	(0.95)		(0.39)	(1.32)	(0.62)	(0.51)	(1.09)	(2.12)	(0.77)	(6.96)				
Portugal	-.41	-.41	.032	10.0	0.2	-1.8	-.007	-.13	.02	.95	2.12	.983	.978	722-834
	(2.85)	(2.85)	(2.21)	(1.82)	(0.07)	(0.61)	(0.80)	(1.30)	(0.26)	(14.80)				

Notes: [a] A is unlagged rather than lagged once.

[b] A is lagged once rather than twice.

[c] Only discount rate data available for R .

NA = sufficient data not available.

1. $\dot{P}_{-1}$: The rate of inflation is assumed to have a positive effect on the interest rate target. Monetary authorities are assumed to tighten up as inflation rises. This is consistent with market-force effects in the theoretical model, where a positive price shock with the money supply unchanged led to an increase in the interest rate. The rate of inflation is lagged once rather than unlagged in the equations in Table 1 because this gave on average somewhat better results.

2. D: D is a measure of demand pressure in the overall multicountry model. It is an explanatory variable in the price equation for each country in the model. It is included in the interest rate equation to pick up possible inflation effects not captured in the inflation variable itself. It may be a better signal for the monetary authorities regarding future inflation than is the inflation variable itself, and it may thus be used by the authorities in setting interest rates.

3. A_{-1} and A_{-2}: A is the normalized real net asset position of the country relative to the rest of the world. The change in A is the real value of the balance of payments except for the normalization by full employment GNP.[6] If the balance of payments of the country is weak, the

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[6]The nominal net asset position of each country relative to the rest of the world is obtained by summing past values of the balance of payments. The real value of net assets is equal to the nominal value divided by the domestic price index. A is then the real value of net assets divided by the full employment measure of real GNP. The creation of the full employment measure of real GNP is explained in Fair (1984), p. 162.

Let A' denote the net asset position of the country before being divided by anything. (A' is thus in nominal terms.) In terms of the variables in the theoretical model, $\Delta A'$ is equal to $-\Delta B_p^* + e\cdot\Delta b_p^* + \Delta Q$, so that equation (36) becomes $0 = S - \Delta A'$. This equation determines $\Delta A'$ in my multicountry model for each country, where A' is then determined as $A'_{-1} + \Delta A'$. S is determined by an equation like (37). Because bilateral monetary authorities may tighten up, and if the balance of payments is strong, the authorities may feel they have room to loosen up. Experiment 6 shows that in the theoretical model with the exchange rate unchanged a decrease in the interest rate expands the economy and worsens the balance of payments.[7] (The theoretical model is roughly symmetric, so that an increase in the interest rate contracts the economy and improves the balance of payments.) The authorities may be thus more likely to lower the interest rate when the balance of payments is strong (and suffer the consequences of some fall in the balance of payments) than when it is weak. The coefficients on A_{-1} and A_{-2} were not constrained to be equal in absolute value and of opposite signs. There may be both level and rate of change effects, and in general it is of interest to see if the data support a negative coefficient for A_{-1} and a positive coefficient for A_{-2}. In some cases the use of A_0 and A_{-1} gave better results than did the use of A_{-1} and A_{-2}, and in these cases the results presented in Table 1 are for A_0 and A_{-1}.

4. $\dot{M}_{-1}$: A rapid growth of the money supply may lead the monetary authority to raise interest rates in the future in an attempt to lessen the growth. The past growth rate of the money supply may thus have a positive

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security demand equations are not estimated, it is not possible to determine B_p^*, b_p^*, and Q separately in the model.

[7]The use of experiment 6 to justify using A_{-1} and A_{-2} in the interest rate equation is not quite right. In experiment 6 the exchange rate was taken to be unchanged. In the estimated exchange rate equation below, on the other hand, the interest rate has an effect on the exchange rate. Therefore, according to the estimated equations, the monetary authorities know that if they change the interest rate this will affect the exchange rate, which is contrary to the assumption of experiment 6. What needs to be assumed here is that the exchange rate movement from a change in R is not so large as to reverse the results of experiment 6 regarding the effects on S.

effect on the current value of the interest rate. If monetary authorities are interested in both money supply growth and interest rate values, one way of trying to capture this is to add the lagged growth of the money supply to the interest rate equation. Note that this effect is not the effect observed in experiment 2 for the theoretical model, where an increase in the money supply led to a decrease in R. Although this contemporaneous effect is negative, the lagged effect of the money supply on the interest rate may be positive.

5. R_{US}: The monetary policies of other countries may be influenced by U.S. monetary policy, and the inclusion of the U.S. interest rate in the equations is an attempt to test for this.

6. R_{GE}: The German interest rate is included in the interest rate equations for the European countries. It may be that the monetary policies of other European countries are influenced by German monetary policy.

7. R_{-1}: Monetary authorities are likely to dislike large short run changes in interest rates and thus try to avoid them. One way of trying to capture this effect is by the use of the lagged dependent variable, and this is what is done here. Monetary authorities are assumed to adjust only partially to their desired interest rate targets in any one quarter. The lagged dependent variable may also be picking up expectational effects.[8]

Each equation in Table 1 was estimated by two stage least squares

[8]Lagged dependent variables are freely used in my multicountry econometric model with the aim of accounting for partial adjustment and/or expectational effects. This "traditional" procedure was tested in Fair (1986) using my U.S. model against a procedure that allows expectations to be formed in more sophisticated ways, including formed rationally. The results provide no strong support for the more sophisticated hypothesis. Both the traditional procedure and the more sophisticated one lead to very similar results, including results about policy properties. This is thus some justification for the use of the present approach.

(2SLS) under the assumption of first order serial correlation of the error term. The first stage regressors for each country are the main predetermined variables in my multicountry model for that country.[9] The sample periods begin near the start of flexible exchange rates and end at the latest available data at the time this study was undertaken.

Only a little "searching" was done for the results in Table 1. As noted above, the inflation variable lagged once seemed to give better results than the variable unlagged, and so the variable lagged once was used for all the equations. In most cases the asset variable lagged once and twice gave better results than did the variable unlagged and lagged once. As noted above, in cases where the variable unlagged and lagged once gave better results, these results are presented in the table. These cases are the equations for Canada, Belgium, Norway, Sweden, and the U.K.

One should be aware in interpreting the results that collinearity can be a serious problem in trying to get precise estimates. The sample periods are fairly short; the inflation variable and the demand pressure variable are likely to be highly correlated; and the two values of the asset variable are likely to be highly correlated. One should thus not necessarily expect very precise coefficient estimates. In what follows a variable will be said to be "significant" if the t-statistic of its coefficient estimate is greater than two in absolute value.

If the estimate of the serial correlation coefficient was not significantly different from zero for a country, the equation was reestimated with the serial correlation coefficient constrained to be zero.

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[9]The list of first stage regressors for each equation estimated in this paper is available from the author upon request.

Serial correlation is in fact not a problem for the interest rate equations. For only three countries -- Canada, Denmark, and Portugal -- was the estimate significant.

Consider now the coefficient estimates for the explanatory variables in Table 1. The results are quite good for the asset variable. One expects a negative coefficient on A_{-1} (or A_0) and a positive coefficient on A_{-2} (or A_{-1}). The signs are as expected except for Portugal. In other words, 32 of the 34 estimates are of the right sign. The results are also good for the demand pressure variable, where only 3 of the 17 coefficient estimates are of the wrong sign. The results are not good for the inflation variable itself, where 8 of the 17 estimates are of the wrong sign. It appears that it is primarily the demand pressure variable that is picking up the effects of expected future inflation on interest rate targets. The results are likewise not good for lagged money supply growth, where 9 of the 17 estimates are of the wrong sign. The U.S. interest rate has coefficient estimates of the right sign in all but two cases -- Japan and Portugal. The German interest rate has coefficient estimates of the right sign in 8 of the 13 European equations. All the coefficient estimates of the lagged dependent variable are positive and large.

The equations in Table 1 were reestimated with the variables with the wrong signs dropped, and these results are presented in Table 2. In a few cases dropping one variable with the wrong sign led to another variable developing the wrong sign, and in these cases variables continued to be dropped until there were no wrong signs among the remaining variables. The equations in Table 2 are used for the tests in the next section.

Aside from the lagged dependent variable and the U.S. interest rate,

TABLE 2. Estimates of the interest rate equations. Wrong signs dropped. Dependent variable is R.

	$\hat{\rho}$	$\dot{P}_{-1}$	D	A_{-1}	A_{-2}	$\dot{M}_{-1}$	R_{US}	R_{GE}	R_{-1}	DW	SE	R^2
Canada	.41	.006	—	-59.9[a]	59.0[b]	.005	.76	—	.45	1.87	.673	.969
	(3.14)	(0.18)		(3.76)	(3.67)	(0.91)	(10.59)		(7.94)			
Japan	0	.026	—	-47.7	58.1	.004	—	—	.82	1.64	.665	.928
		(1.29)		(4.83)	(5.52)	(0.53)			(15.93)			
Australia	0	—	31.6	-13.3	12.1	—	.06	—	.91	1.88	.946	.897
			(3.41)	(1.52)	(1.40)		(1.21)		(12.49)			
Germany	0	.036	24.9	-17.1	10.8	—	.15	—	.69	2.40	.645	.935
		(1.17)	(2.67)	(1.68)	(1.14)		(2.11)		(10.46)			
Austria[c]	0	.018	1.7	-9.3	11.4	.003	.16	.00	.71	1.93	.460	.823
		(1.50)	(0.56)	(2.04)	(2.37)	(0.56)	(3.06)	(0.05)	(10.13)			
Belgium	0	—	13.4	-20.1[a]	16.8[b]	—	.20	.03	.64	1.83	1.213	.836
			(1.44)	(1.47)	(1.37)		(1.50)	(0.27)	(7.79)			
Denmark	-.29	.264	22.3	-96.2	90.2	—	—	.10	.58	2.19	2.091	.738
	(1.93)	(3.88)	(2.11)	(4.76)	(4.58)			(1.11)	(6.09)			
France	0	—	21.3	-58.9	37.9	.008	.31	.32	.49	1.60	.862	.918
			(2.49)	(3.33)	(2.43)	(0.61)	(4.19)	(3.97)	(6.25)			
Italy	0	—	12.4	-42.7	36.2	.047	.20	—	.66	1.46	1.186	.931
			(1.21)	(4.06)	(3.77)	(2.53)	(2.42)		(7.47)			
Netherlands	0	—	16.5	-3.1	11.0	—	.39	.37	.41	1.81	1.653	.749
			(2.64)	(0.21)	(0.73)		(2.50)	(2.25)	(4.14)			
Norway	0	—	—	-2.3[a]	2.3[b]	.004	.22	—	.70	2.33	1.553	.713
				(0.35)	(0.34)	(0.54)	(1.59)		(7.80)			
Sweden	0	.060	29.1	-4.6[a]	3.0[b]	NA	.06	.07	.71	1.77	1.085	.909
		(1.73)	(2.79)	(0.45)	(0.30)		(0.59)	(0.79)	(7.25)			
Switzerland	0	—	5.1	-11.9	9.2	—	.19	—	.54	1.25	.562	.898
			(1.21)	(2.25)	(1.80)		(3.17)		(6.54)			
U.K.	0	—	12.6	-13.5[a]	14.6[b]	.009	.24	—	.77	1.54	1.110	.812
			(1.70)	(1.06)	(1.21)	(0.55)	(3.21)		(9.05)			
Finland	0	—	2.3	-7.7	7.5	—	.06	—	.92	1.52	.749	.918
			(0.34)	(1.68)	(1.51)		(1.49)		(21.57)			
Ireland	0	.009	13.8	-5.1	3.8	—	.25	—	.66	1.65	1.427	.844
		(0.41)	(1.34)	(0.78)	(0.61)		(1.99)		(7.25)			
Portugal	-.24	.040	—	—	—	—	—	—	.99	1.95	1.108	.973
	(1.65)	(2.68)							(46.79)			

Notes: [a] A is unlagged rather than lagged once.

[b] A is lagged once rather than twice.

[c] Only discount rate data available for R .

NA = sufficient data not available.

the asset variable is the most significant variable in Table 2. Seven of the coefficient estimates are significant for A_{-1} (or A_0), and six are significant for A_{-2} (or A_{-1}). Six of the estimates for the demand pressure variable are significant; only two of the estimates for the inflation variable are significant. Only one of the estimates of the lagged money growth variable is significant.

Exchange Rate Equations

Estimated exchange rate equations are presented in Table 3 for 17 countries. As was the case for the interest rate equations, the same set of explanatory variables was tried for each country. The general form of the exchange rate equation is

$$(39) \quad e = f(\overset{+}{P/P_{US}}, \overset{-}{(1+R)/(1+R_{US})}, \overset{+}{e_{GE}}, \overset{+}{e_{-1}}) ,$$

where e is the country's exchange rate relative to the U.S. dollar, P/P_{US} is the country's aggregate price level relative to the price level of the United States, $(1+R)/(1+R_{US})$ is one plus the country's interest rate relative to the same variable for the United States, and e_{GE} is the German exchange rate relative to the U.S. dollar. The choice of the explanatory variables will now be discussed. Remember that an increase in e is a depreciation of the country's currency relative to the U.S. dollar. Also note in Table 3 that the functional form chosen for the exchange rate equation is the log form.

1. P/P_{US}: In the theoretical model a positive price shock led to a depreciation, and so one expects a positive coefficient for the country's relative price level. In other words, a relative price increase in a

TABLE 3. Estimates of the exchange rate equations. Dependent variable is log e

	$\hat{\rho}$	$\log(P/P_{US})$	$\log\frac{(1+R)^{.25}}{(1+R_{US})^{.25}}$	$\log e_{GE}$	$\log e_{-1}$	DW	SE	R^2	Sample
Canada	.31 (2.39)	.14 (1.39)	-.90 (0.81)	—	.98 (27.60)	1.90	.0131	.985	711-854
Japan	.83 (7.30)	.36 (1.47)	-1.49[a] (0.66)	—	.48 (2.58)	1.84	.0432	.891	722-854
Australia	0	.18 (2.89)	2.17 (2.36)	—	.91 (20.24)	1.86	.0365	.964	722-854
Germany	.44 (2.35)	-.10 (0.80)	-1.96[a] (0.90)	—	.87 (8.09)	2.14	.0431	.923	741-854
Austria	.81 (8.95)	.15 (2.33)	-1.21 (2.33)	.96 (60.89)	.03 (1.64)	1.63	.0054	.999	722-861
Belgium	.98 (36.40)	-.22 (0.93)	-.74 (1.14)	.90 (18.66)	.12 (2.22)	1.09	.0155	.994	722-844
Denmark	.99 (60.87)	.05 (0.23)	-.23[a] (0.58)	.85 (17.90)	.09 (1.76)	1.36	.0146	.995	722-844
France	.77 (7.17)	1.17[a] (6.22)	-.30[a] (0.25)	.71 (10.59)	.31 (4.17)	1.88	.0237	.992	722-854
Italy	.76 (7.03)	.67[a] (5.95)	-1.46[a] (1.26)	.51 (6.76)	.38 (4.14)	2.23	.0266	.995	722-853
Netherlands	.81 (10.05)	-.27 (2.69)	-.61[a] (2.12)	.89 (30.61)	.07 (2.33)	2.19	.0097	.996	722-844
Norway	.99 (29.77)	.12[a] (0.45)	-.76 (1.18)	.66 (12.63)	.20 (2.56)	1.43	.0171	.987	722-844
Sweden	.81 (8.44)	1.32 (6.59)	-1.08 (0.86)	.60 (9.53)	.33 (4.22)	1.70	.0238	.992	722-853
Switzerland	.86 (9.25)	.80 (3.07)	-1.91[a] (1.34)	.91 (10.44)	.01 (0.16)	1.44	.0280	.987	722-843
U.K.	.35 (2.31)	.22 (0.55)	-2.16 (0.95)	.29 (3.54)	.74 (8.79)	2.11	.0413	.963	722-861
Finland	.97 (57.39)	-.53 (2.13)	1.46 (1.00)	.65 (10.14)	.14 (1.56)	2.13	.0229	.984	722-854
Ireland	.95 (38.37)	.37 (1.72)	-1.45[a] (1.59)	.73 (8.10)	.03 (0.29)	2.14	.0271	.988	722-844
Portugal	.37 (2.35)	.69[a] (5.39)	3.35 (2.37)	.44 (5.61)	.49 (4.84)	1.87	.0327	.995	722-834

Note: [a]Variable is lagged once rather than unlagged.

country is likely to put downward pressure on the country's currency relative to the U.S. dollar, and the monetary authorities may go along with this. In a few cases the relative price variable lagged once gave better results than did the variable unlagged, and in these cases the results presented in Table 3 are for the lagged variable.

2. $(1+R)/(1+R_{US})$:[10] In the theoretical model a decrease in the domestic interest rate led to a depreciation, and so one expects a negative coefficient for the relative interest rate variable. In about half the cases the relative interest rate variable lagged once gave better results than did the variable unlagged, and in these cases the lagged variable was used for the results in Table 3.

3. e_{GE}: The monetary authorities of other European countries may be influenced by the German exchange rate in deciding on their own exchange rate targets. The use of the German rate is also an attempt to capture some of the effects of the European Monetary System (EMS). Under the assumption that Germany is the dominate country in the EMS, the German rate will pick up some of the effects of the EMS agreement. As will be seen, the German rate is a highly significant variable with a large coefficient estimate in all the European equations. The European equations can be looked upon in large part as explaining <u>deviations</u> of the particular country's rate from the German rate.

4. The lagged dependent variable. This variable is included for the

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[10] The interest rates in the data are at annual rates, and so one plus the interest rate has been raised to the one-fourth power in the empirical work to put the variables at quarterly rates. This is so indicated in Tables 3-5. It should also be noted that the interest rates in Tables 1 and 2 are in percentage points (1 percent =1.0), whereas in Tables 3-5 they are in percents (1 percent = .01).

same reasons that the lagged dependent variable was included in the interest rate equation, namely to pick up partial adjustment and expectational effects.

As with the interest rate equations, the exchange rate equations have been estimated by 2SLS under the assumption of first order serial correlation of the error term. The first stage regressors for each country are the main predetermined variables in the multicountry model for that country. The sample periods are the same as were used for the interest rate equation. No searching was done for the exchange rate equations except to try both the current and lagged values of the relative price and relative interest rate variables.

The results in Table 3 seem reasonably good for the price and interest rate variables. Only 4 of the 17 coefficient estimates for the relative price variable have the wrong sign, and only 3 of the 17 estimates for the relative interest rate variable have the wrong sign. On the negative side, all the equations except the equation for Australia have significant estimates of the serial correlation coefficient. The German exchange rate is highly significant in the European equations. The coefficient estimates of the lagged dependent variables are all positive, although some estimates are quite small.

The equations in Table 3 were reestimated with the variables with the wrong signs dropped, and these results are presented in Table 4. The equations in Table 4 are used for the tests in the next section. The results in Table 4 show that 7 of the coefficient estimates for the relative price variable are significantly different from zero. The interest rate coefficients are not estimated very precisely. Only two of the estimates

TABLE 4. Estimates of the exchange rate equations. Wrong signs dropped. Dependent variable is log e.

	$\hat{\rho}$	$\log(P/P_{US})$	$\log\frac{(1+R)^{.25}}{(1+R_{US})^{.25}}$	$\log e_{GE}$	$\log e_{-1}$	DW	SE	R^2
Canada	.31 (2.39)	.14 (1.39)	-.90 (0.81)	—	.98 (27.60)	1.90	.0131	.985
Japan	.83 (7.30)	.36 (1.47)	-1.49[a] (0.66)	—	.48 (2.58)	1.84	.0432	.891
Australia	0	.18 (2.76)	—	—	.95 (21.88)	1.69	.0379	.961
Germany	.45 (2.48)	—	-2.78[a] (1.41)	—	.89 (8.74)	2.15	.0434	.922
Austria	.81 (8.95)	.15 (2.33)	-1.21 (2.33)	.96 (60.89)	.03 (1.64)	1.63	.0054	.999
Belgium	.99 (40.32)	—	-.69 (1.06)	.90 (18.61)	.11 (2.08)	1.09	.0154	.994
Denmark	.99 (60.87)	.05 (0.23)	-.23[a] (0.58)	.85 (17.90)	.09 (1.76)	1.36	.0146	.995
France	.77 (7.17)	1.17[a] (6.22)	-.30[a] (0.25)	.71 (10.59)	.31 (4.17)	1.88	.0237	.992
Italy	.76 (7.03)	.67[a] (5.95)	-1.46[a] (1.26)	.51 (6.76)	.38 (4.14)	2.23	.0266	.995
Netherlands	.95 (17.74)	—	-.71[a] (2.63)	.89 (29.45)	.07 (2.03)	2.23	.0099	.996
Norway	.99 (29.71)	.12[a] (0.45)	-.76 (1.18)	.66 (12.63)	.20 (2.56)	1.43	.0171	.987
Sweden	.81 (8.44)	1.32 (6.59)	-1.08 (0.86)	.60 (9.53)	.33 (4.22)	1.70	.0238	.992
Switzerland	.86 (9.25)	.80 (3.07)	-1.91[a] (1.34)	.91 (10.44)	.01 (0.16)	1.44	.0280	.987
U.K.	.35 (2.31)	.22 (2.55)	-2.16 (0.95)	.29 (3.54)	.74 (8.79)	2.11	.0413	.963
Finland	.97 (42.79)	—	—	.61 (10.47)	.15 (1.88)	1.86	.0217	.985
Ireland	.95 (38.37)	.37 (1.72)	-1.45[a] (1.59)	.73 (8.10)	.03 (0.29)	2.14	.0271	.988
Portugal	.70 (5.95)	.95[a] (6.55)	—	.57 (5.90)	.37 (3.55)	2.00	.0324	.995

Note: [a]Variable is lagged once rather than unlagged.

are significant.

The Monetary Approach to Exchange Rate Determination

It is of interest to compare the present exchange rate equation with the equation derived from what is usually called the monetary approach to exchange rate determination. In the basic equation of the monetary approach the exchange rate is a function of the relative money supplies of the two countries, the relative income levels, and the relative interest rates.[11] The money supply variable should have a coefficient of one, the income variable a negative coefficient, and the interest rate variable a positive coefficient. The equation estimated in Table 3 already has a relative interest rate variable, and so if one adds a relative money supply variable and a relative income variable to the equation, one has the monetary approach equation. If the monetary approach is correct, the relative price variable does not belong in the equation (and so should be insignificant) and the relative interest rate variable should change signs from negative to positive when the money supply and income variables are added.

The results of adding the relative money supply and income variables to the Table 3 equations are presented in Table 5. The equations have been estimated by 2SLS with account taken of first order serial correlation of the error term, where both the money and income variables are taken to be endogenous (as well as the price and interest rate variables). It seems clear that the results are not supportive of the monetary approach. Eleven of the 17 coefficient estimates of the money supply variable are negative

[11]See, for example, equation (19.11) in Levich (1985, p. 1008).

TABLE 5. Estimates of the exchange rate equations with money and income variables added. Dependent variable is log e.

	$\hat{\rho}$	$\log(P/P_{US})$	$\log\frac{(1+R)^{.25}}{(1+R_{US})^{.25}}$	$\log e_{GE}$	$\log e_{-1}$	$\log(M/M_{US})$	$\log(Y/Y_{US})$	DW	SE	R^2
Canada	.39 (2.88)	-.10 (0.57)	-1.59 (1.32)	—	.97 (22.00)	.002 (0.04)	.410 (1.81)	1.91	.0138	.984
Japan	.68 (2.00)	.26 (0.49)	-1.97[a] (0.79)	—	.64 (1.89)	-.334 (0.81)	-.205 (0.25)	1.82	.0438	.888
Australia	0	.42 (2.77)	-.56 (0.36)	—	.93 (19.79)	-.219 (1.60)	.706 (2.23)	1.96	.0371	.963
Germany	.35 (1.90)	-.07 (0.49)	-3.49[a] (1.50)	—	.80 (7.68)	-.427 (1.60)	.007 (0.01)	1.98	.0408	.931
Austria	.68 (5.66)	.12 (2.07)	-.60 (1.39)	.97 (62.96)	.01 (0.73)	-.055 (1.31)	-.156 (1.96)	1.62	.0054	.999
Belgium	.98 (35.73)	-.09 (0.37)	-.49 (0.79)	.91 (18.61)	.10 (1.81)	-.074 (0.50)	.049 (0.51)	1.13	.0153	.994
Denmark	.99 (61.57)	-.01 (0.03)	-.20[a] (0.49)	.84 (17.86)	.09 (1.70)	-.027 (0.38)	.023 (0.34)	1.40	.0145	.995
France	.73 (6.96)	.75[a] (2.59)	-.21[a] (0.18)	.69 (10.31)	.33 (4.57)	.318 (1.90)	.129 (0.33)	1.91	.0227	.993
Italy	.39 (2.35)	-.41 (1.16)	3.28 (2.30)	.58 (7.44)	.50 (5.77)	.873 (3.03)	-.194 (0.71)	2.04	.0247	.996
Netherlands	.88 (15.77)	-.13 (1.14)	-.75[a] (2.80)	.89 (32.36)	.06 (1.82)	-.141 (2.43)	-.156 (1.78)	2.46	.0092	.996
Norway	.99 (32.32)	.07[a] (0.24)	-.25 (0.43)	.67 (12.84)	.19 (2.42)	-.009 (0.21)	-.042 (0.49)	1.46	.0171	.987
Sweden	.80 (7.63)	1.17 (4.87)	-1.38 (1.07)	.60 (9.74)	.32 (4.09)	.109 (1.15)	.050 (0.18)	1.66	.0234	.992
Switzerland	.87 (10.49)	.89 (2.73)	-2.13[a] (1.49)	.81 (7.34)	.02 (0.16)	-.268 (1.51)	-.198 (0.57)	1.30	.0277	.987
U.K.	.22 (1.17)	.36 (2.16)	-2.70 (1.31)	.27 (3.94)	.81 (7.39)	-.137 (0.79)	.466 (1.01)	1.99	.0417	.962
Finland	.97 (75.38)	-.66 (2.61)	2.38 (1.76)	.66 (10.20)	.12 (1.35)	-.140 (1.72)	-.170 (1.33)	2.13	.0227	.984
Ireland	.95 (34.08)	.33 (1.45)	-1.42[a] (1.55)	.72 (8.10)	.05 (0.42)	.064 (0.36)	.004 (0.03)	2.10	.0268	.989
Portugal	.83 (9.64)	.67[a] (3.24)	1.45 (0.84)	.61 (6.38)	.36 (3.59)	.353 (2.24)	-.142 (0.83)	2.02	.0312	.996

Note: [a]Variable is lagged once rather than unlagged.

rather than positive,[12] and 9 of the 17 estimates of the income variable are positive rather than negative. Only 3 of the 17 estimates of the interest rate variable are positive.

It is interesting to note that the basic equation tested by Meese and Rogoff is the equation implied by the monetary approach. Since the data do not seem to support this equation, it is not surprising that the equation did not do well in their tests.

Interest Rate and Exchange Rate Effects on One Another

The interest rate and exchange rate equations have the characteristic that the exchange rate equation has the interest rate in it, but not vice versa. Implicit in this treatment is the assumption that the monetary authorities make decisions sequentially. It is assumed that they first decide on their interest rate target as a function of a number of variables (not including the exchange rate). They then decide on their exchange rate target, given the interest rate value and their knowledge of the market forces on the exchange rate that this value implies.

It may be, of course, that the exchange rate affects the interest rate as well as vice versa. If this is true, it can be incorporated in the

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[12] With the lagged dependent variable in the equation, one does not necessarily expect the coefficient of the money variable to be one. It should only be one in the long run, which means that the coefficient estimate for the money variable when divided by one minus the coefficient estimate for the lagged dependent variable should be one. The coefficient estimate for the money variable should, of course, not be negative. One might argue that the lagged dependent variable does not belong in the equation, depending on the dynamics that one is assuming, but this simply means in the present context that the coefficient estimates of the lagged dependent variable in Table 5 should be insignificant. Note that the lagged dependent variable estimates are not picking up first order serial correlation of the error term, because serial correlation has been taken into account in the estimation.

present approach by simply adding the exchange rate as an explanatory variable in the interest rate equation. To test for this, log e was added to the equations in Table 2. Fourteen of the 17 coefficient estimates were positive. Three of the estimates were significant (all positive) -- those for Norway, Finland, and Portugal. Ten of the 17 estimates had t-statistics less than one in absolute value. The effects on the other coefficient estimates from the addition of log e were minor. Very similar results were obtained when log e_{-1} was added rather than log e. These results are thus not very strong support for the hypothesis that the exchange rate affects the interest rate target, although the fact that 14 of the 17 estimates were of the same sign is perhaps mild support. Given the weak results, it was decided not to include the exchange rate in the interest rate equations for the tests in the next section.

Conclusion

What is one to make of the results in Tables 2 and 4? Given the short sample periods, the results do not seem too bad. Inflationary effects (primarily through the demand pressure variable) and net asset effects on short term interest rates appear to be picked up in Table 2. Similarly, relative price effects and relative interest rate effects on exchange rates appear to be picked up in Table 4. An interesting question is how these equations stand up against the Meese and Rogoff type of tests, and this will now be explored.

IV. The Tests

The interest rate and exchange rate equations are tested against two alternatives in this section. One is the assumption that the two variables follow random walks, and the other is the assumption that they follow a sixth order autoregressive equation with a constant and time trend included. There are thus three equations per variable, which will be labeled structural, RW, and AR6. In order to avoid giving the structural model a possibly unfair advantage over the AR6 model, the U.S. and German interest rates have been included in the AR6 equations for the interest rate (the German rate included only for the European countries). Similarly, the German exchange rate has been included in the AR6 equations for the exchange rate for the European countries.

The tests are as follows. Each structural and AR6 equation was estimated 8 times, the first sample period ending 9 quarters before the end of the data for the country, the second ending 8 quarters before, and so on. For each set of estimates, outside sample forecasts were made. The forecast period was 4 quarters. There were thus 8 one-quarter-ahead forecasts, 7 two-quarter-ahead forecasts, 6 three-quarter-ahead forecasts, and 5 four-quarter-ahead forecasts. The same forecasts for the RW equations were made. (The RW equations required no estimation. Each variable is simply equal to its value last period. No constant term was included in RW equations.) Root means squared errors were then computed for the forecasts. The results for the interest rate are presented in Table 6, and the results for the exchange rate are presented in Table 7. The interest rate errors are in percentage points, and the exchange rate errors are percentage errors in percentage points.

Consider first the interest rate errors. For the one-quarter-ahead errors the structural model is best in 3 cases, the AR6 model is best in 7

TABLE 6. Root mean squared errors of outside sample forecasts. Interest rate equations. Errors are in percentage points.

	Last quarter used	Table 2 equation Quarters ahead (number of observations)				AR6 equation Quarters ahead (number of observations)				Random walk Quarters ahead (number of observations)			
		1 (8)	2 (7)	3 (6)	4 (5)	1 (8)	2 (7)	3 (6)	4 (5)	1 (8)	2 (7)	3 (6)	4 (5)
Canada	844	.56	.74	.82	.83	.66	.83	1.01	1.26	.93	1.54	1.92	1.95
Japan	854	.40	.45	.62	.59	.40	.57	.56	.53	.41	.51	.46	.49
Australia	854	2.04	3.18	4.11	5.16	2.14	2.71	2.55	2.22	2.05	3.16	3.64	4.05
Germany	854	.35	.49	.51	.55	.24	.29	.22	.12	.30	.52	.56	.55
Austria	861	.29	.44	.56	.73	.34	.64	.93	1.31	.20	.28	.37	.40
Belgium	844	1.49	2.46	3.25	3.90	.92	1.28	1.31	1.01	1.09	.193	2.36	2.27
Denmark	844	3.05	3.65	3.22	2.86	4.07	6.35	6.91	7.39	2.93	4.74	4.72	4.44
France	854	.49	.55	.49	.31	.40	.81	1.12	1.37	.46	.89	1.30	1.72
Italy	853	1.18	1.81	2.14	2.30	.46	.60	.53	.58	.62	1.04	1.40	1.52
Netherlands	844	1.35	1.75	1.32	1.12	1.28	2.25	2.72	3.09	.55	.56	.57	.61
Norway	844	1.30	1.89	2.51	2.95	.59	.72	.80	.88	.80	.52	.71	.69
Sweden	853	1.28	1.74	1.86	2.28	1.50	1.86	1.46	1.63	1.44	1.90	1.76	2.40
Switzerland	843	.62	.68	.63	.73	.89	1.36	1.80	2.11	.57	.73	.68	.56
U.K.	861	1.48	1.90	2.32	2.89	1.47	1.66	2.04	2.34	1.23	1.43	1.74	2.25
Finland	854	.81	1.51	2.41	3.51	.76	.98	1.41	2.08	.79	1.36	2.03	2.79
Ireland	844	1.77	1.78	1.79	1.56	1.98	2.31	2.51	2.79	1.53	1.97	2.44	2.79
Portugal	834	1.64	2.20	3.08	3.93	1.35	1.38	1.77	1.92	1.62	2.45	3.51	4.77

TABLE 7. Root mean squared errors of outside sample forecasts. Exchange rate equations. Errors are percentage errors in percentage points.

	Last quarter used	Table 4 equation Quarters ahead (number of observations)				AR6 equation Quarters ahead (number of observations)				Random walk Quarters ahead (number of observations)			
		1 (8)	2 (7)	3 (6)	4 (5)	1 (8)	2 (7)	3 (6)	4 (5)	1 (8)	2 (7)	3 (6)	4 (5)
Canada	844	1.6	2.8	3.6	5.0	1.1	1.8	2.0	2.6	1.7	3.0	4.2	5.5
Japan	854	5.8	9.2	12.7	11.0	5.8	9.3	13.5	13.9	6.3	9.4	11.4	10.6
Australia	854	6.7	10.4	13.4	17.4	7.2	12.8	17.3	22.3	6.6	10.4	14.3	18.7
Germany	854	5.3	11.6	16.6	15.0	6.6	13.3	19.5	16.8	6.3	11.2	14.4	13.6
Austria	861	0.4	0.5	0.6	0.6	1.1	1.3	1.5	1.6	7.2	13.8	19.0	21.3
Belgium	844	0.7	1.2	1.7	1.8	2.5	3.6	4.2	5.0	4.2	7.2	9.3	11.5
Denmark	844	0.8	1.0	0.9	1.0	3.3	4.5	5.5	6.8	4.0	7.0	9.2	11.3
France	854	2.8	5.2	7.6	8.7	5.3	9.5	12.5	14.4	6.3	11.1	14.4	13.6
Italy	853	2.5	3.6	4.6	3.7	3.2	5.1	5.4	5.9	4.3	7.6	10.4	13.6
Netherlands	844	0.9	1.6	2.0	2.6	0.9	0.9	0.9	1.0	4.2	7.1	8.9	10.7
Norway	844	1.4	2.4	3.0	3.5	2.9	4.9	6.2	7.6	3.6	6.3	8.0	10.0
Sweden	853	2.7	4.0	5.9	7.8	6.6	13.0	17.8	23.0	4.0	6.5	7.6	9.4
Switzerland	843	1.6	2.3	2.3	2.1	3.5	5.3	5.9	5.7	4.1	5.4	6.2	7.4
U.K.	861	7.6	14.0	19.1	22.5	8.4	16.2	23.1	28.1	7.4	13.3	17.7	19.1
Finland	854	4.5	10.1	15.4	12.7	6.0	9.8	11.8	13.0	5.3	9.3	12.0	11.1
Ireland	844	2.3	3.9	4.2	4.9	2.5	2.6	2.7	2.7	4.5	8.1	10.8	13.2
Portugal	834	5.7	8.4	11.1	13.2	4.5	6.0	5.2	5.0	9.3	17.3	23.4	28.2

cases, and the RW model is best in 6 cases. In one case the structural and RW models tied. For the four-quarter-ahead errors the structural model is best in 4 cases, the AR6 model is best in 7 cases, and the RW model is best in 6 cases. The results are thus mixed, with the structural model doing somewhat less well than the other two.

Consider next the exchange rate errors. For the one-quarter-ahead errors the structural model is best in 11 cases, the AR6 model is best in 2 cases, and the RW model is best in 2 cases. In 2 cases the structural and AR6 models tied. For the four-quarter-ahead errors the structural model is best in 9 cases, the AR6 model is best in 4 cases, and the RW model is best in 4 cases. The results are thus in general supportive of the structural model over the other two.

Results like those in Tables 6 and 7 must be interpreted with considerable caution. The estimation periods for the equations are short, and there are at most only 8 outside-sample forecast observations. Also, the simple comparison of outside sample root mean squared errors can be improved upon, at least in the long run.[13] More observations are needed before much can be said about either the interest rate or the exchange rate equation. Nevertheless, one would certainly not conclude from the exchange rate results that the structural exchange rate equation is poor relative to the AR6 and RW equations. If anything, the reverse is true. Meese and Rogoff's general conclusion for exchange rate equations thus seems too

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[13]With more observations one can use the method in Fair (1980) to compare the alternative models. Unlike the simple RMSE comparison, this method accounts for the fact that forecast error variances vary across time and for the uncertainty from the exogenous variable forecasts. It also accounts in an explicit way for the possible misspecification of the models.

pessimistic for the present equations. It may be that over time reasonable structural exchange rate equations can be estimated.

APPENDIX

In order to solve the theoretical model in Section II numerically, one needs to specify the functional forms and coefficients for equations (1), (2), (3), (6), (7), and (10) and the equivalent equations for country 2. The specifications used in this paper are the following:

(1) $X_p = -40.0 \cdot P + 40.0 \cdot e \cdot p - 571.0 \cdot R + .40 \cdot Y + 30.97$,

(2) $x_p^* = 40.0 \cdot p - 40.0 \cdot e \cdot p - 286.0 \cdot R + .20 \cdot Y + 20.02$,

(3) $P = .10 \cdot e \cdot p + .001 \cdot Y + .8$,

(6) $M_p/P = -1429.0 \cdot R + .50 \cdot Y + 150.03$,

(7) $BO = -50.0 \cdot R - 50.0 \cdot RD$,

(10) $b_p^* = -714.0 \cdot R + 714.0 \cdot [(e_{+1}^e/e)(1+r) - 1]$.

These same coefficient values have been used for country 2's equations.

The entire simulation model consists of the above equations, the equivalent equations for country 2, and the definitions that are presented in Section II. There are 34 independent equations altogether. Given values for the exogenous variables, one can attempt to solve the model for the endogenous variables. The "base" values that have been used in this study are presented in Table A. The base values of the endogenous variables are the solution values that results from solving the model using the base values of the exogenous variables.

The coefficients in the above equations have been chosen to correspond to particular elasticities at the base values. In equation (1) the price elasticities are -1.0 and 1.0, the interest rate elasticity is -1.0, and the income elasticity is 1.0. In equation (2) the four elasticities are -2.0,

TABLE A

Simulation Results for Selected Variables

Experiment	B_g	B^*_p	b^*_p	e	M_b	P	R	r	S	X^*_p	x^*_p	Y	y	Q
1. R lowered	+	-	+	+	+	+	-	0	+	+	-	+	-	0
2. M_b raised	+	-	+	+	+	+	-	-	+	+	+	+	-	0
3. Eq. (3) shocked	-	0	0	+	+	+	0	0	0	-	+	-	+	0
4. Eq. (3) shocked	-	+	-	+	0	+	+	+	-	-	-	-	-	0
5. Eq. (2) shocked	+	+	-	+	0	+	+	+	-	+	+	+	+	0
6. R lowered	+	-	+	0	+	+	-	0	-	+	+	+	+	-

Notes: 1) Base values for country 1:

B_b	0.0	M_b	100.0	S_g	0.0
B_g	0.0	M_p	100.0	S_p	0.0
B_p	-50.0	P	1.0	T_p	40.0
B^*_p	50.0	Q	0.0	TX	.40
BO	0.0	R	.07	X_g	40.0
BR	20.0	RD	.07	X_p	40.0
e	1.0	RR	.20	X^*_p	20.0
e^e_{+1}	1.0	S_b	0.0	Y	100.0

2) Same base values for country 2.

3) Size of changes for the experiments (Q exogenous except for experiment 6):
   1. R lowered by .0005, r exogenous.
   2. M_b raised by 1.0, m_b exogenous.
   3. Equation (3) shocked by .01, R and r exogenous.
   4. Equation (3) shocked by .01, M_b and m_b exogenous.
   5. Equation (2) shocked by .5, M_b and m_b exogenous.
   6. R lowered by .0005, r exogenous, e exogenous.

4) For experiment 2 R decreased more than did r .

5) For experiments 4 and 5 R increased more than did r .

2.0, -1.0, and 1.0. In equation (3) the import price elasticity is .1 and the income elasticity is .1. In equation (6) the interest rate elasticity is -1.0 and the income elasticity is .5. In equation (7), which is not an important equation in the model, elasticities are not defined because the base value of BO is zero. Coefficients of 50 and -50 have been used. In equation (10) the interest rate elasticities are -1.0 and 1.0.

Summary results from the experiments are reported in Table A. These are the experiments discussed in Section II. Remember that lower case letters denote variables for country 2, so that, for example, r is country 2's interest rate and y is country 2's GNP.

One should, of course, be aware of the limitations of theoretical simulation models. Even though only the qualitative results are stressed in this paper, the qualitative results are not necessarily robust to alternative choices of the coefficients. At least some of the signs in Table A may be reversed with different coefficients. The simulation model is meant to help in understanding the theoretical model, but the results from it should not be taken as evidence that all the signs in Table A hold for all possible coefficient values.

DATA SOURCES

The data used in this paper are data from my multicountry model. The sources for data are listed in Table B-2 in Fair (1984). The following are the links from the variables in Table B-2 to the variables used in this paper.

Current Variable	Variable in Table B-2	Description	
A	$A^*/(PY \cdot Y^*)$	A^* =	net stock of foreign security and reserve holdings in lc.
		PY =	GNP deflator.
		Y^* =	Estimate of full employment real GNP.
D	-ZZ	-ZZ =	$[(Y/POP) - (Y/POP)^*]/(Y/POP)^*$, where (Y/POP) = per capita real GNP, $(Y/POP)^*$ = estimate of full employment per capita real GNP.
e	e	e =	exchange rate, lc per $.
M	$M1^*/POP$	$M1^*$ =	money supply in lc.
		POP =	population in millions.
P	PY	PY =	GNP deflator.
R	RS	RS =	three-month interest rate.
Y	Y/POP	Y =	real GNP.
		POP =	population in millions.

Notes:

lc = local currency.

In the tables a dot over a variable means percentage change at an annual rate. In other words, for a variable X:

$$\dot{X} = 100 \cdot [(X/X_{-1})^4 - 1] .$$

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