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Open Economy Macroeconomics Using Models of Closed Systems

by

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Most theories relating to open economy macroeconomics postulate that exchange rates are determined by actual and expected interest rates and inflation. This paper argues that while these factors, together with income and wealth, may determine the demand for internationally traded assets, no theory of exchange rate determination is complete unless it also takes into account the supply of assets - plus the mechanisms which bring supply into equivalence with demand.

The paper deploys three simple dynamic models of two interdependent economies which together make up a whole world and then explores their properties viewed as a closed system. In the first model, all the exports of one country turn up as imports of the other and vice versa, while exchange rates are fixed and there is no foreign investment. In the second, exchange rates are exogenous but foreign investment takes place. The third model has endogenous exchange rates. The three models are substantially the same as one another, differing from one another mainly in the way they are closed.

No individual part of what follows is new. However these ideas have never before, so far as I know, been put together in the form of a single, dynamic model which can be simulated as a set of processes occurring in real time. The main findings are:

- a) When asset demands and supplies are comprehensively represented in a dynamic model and appropriately brought into equivalence, no vestige of the "price-specie-flow" mechanism survives, even when all foreign balances are settled in gold.
- b) If there are fixed exchange rates with no capital controls (and assuming fiscal policy to be given) one interest rate has to be endogenous. If one country has a current account deficit, its "interest rate" will rise without limit. To put such changes in relative interest rates down to changes in risk premia etc. is to argue in a circle.
- c) With exogenous interest rates, fiscal policy and zero dealings in foreign reserves in each country, the exchange rate is determined each period by supply and demand for internationally traded assets. While expectations about interest rates and other things, including changes in the exchange rate itself, may determine the demand for assets, the supply of assets, determined by trade and budget balances, are equally important, constituting "the other blade of the scissors". The foreign balance and the exchange rate, along with other factors, mutually determine one another in a sequential process.

The first rigorous two country model to analyse exchange rate determination in the market for financial assets, seems to be Tobin and Macedo (c.1980). A similar construction was proposed by Branson and Henderson (1984) and recapitulated in a broad review of exchange rate theory by Isard (1995). However, all of these studies took each country's budget deficit, current balance of payments, aggregate income, production and wealth to be exogenous, concentrating entirely on the way in which the exchange rate would then be determined. *A fortiori*, they all ignored the way in which exchange rates, having been determined in asset markets, feed back with a time lag so as to change absolute and relative prices, trade, income, the supply and demand for assets and so back to exchange rates themselves.

What follows leaves many important matters untouched. But let no-one be shocked by the rudimentary treatment of expectations. We must have a model before we can derive "model consistent" expectations.

### **AN ACCOUNTING SYSTEM WITH NO BLACK HOLES**

Any rigorous account of the world economy as a system requires a watertight set of accounts to underpin it. The accounts may be more or less simplified, but no model of a whole system is acceptable unless it is grounded in stock and flow matrices in which all rows and all columns sum to zero and unless the model can then explain all the stock and flow variables which it comprises and which are not exogenous.

Table 1 sets out Model 1 balance sheets for the two economies, which will be called "euro" (#) and "dollar" (\$). Household wealth (V) consists of only two assets - money (H) and bonds (B). "Bonds" are all perpetuities, that is, titles to one unit of currency per period. The first currency symbol refers to the country in which the asset is held, the second to the country where the bond is issued. In Model 1 no bonds are internationally traded so the suffixes ## and \$\$ simply mean that the bond in question was both issued and held in the same country. Bond rates of interest (rb# and rb\$) are equal to  $1/pb\#$  and  $1/pb\$$  where pb is the price of a bond. The value of a bond is the piece of paper times its price (e.g.  $B\#\cdot pb\#$ ). Bars of gold are called "or"; the euro price of gold (pg#) is related to the dollar price (pg\$) by the exchange rate ( $xr\# = 1/xr\$$ ). Total government

debt (DG) equals the government's financial liabilities less gold reserves.

**Table 1 Balance Sheets**

	H'Ids#	Govt.#		H'Ids\$	Govt.\$	$\Sigma$
Money	+H#	-H#		+H\$	-H\$	0
Bonds	+B##.pb#	-B##.pb#		+B\$\$ .pb\$	-B\$\$ .pb\$	0
Gold reserves		+or#.pg#	.xr#		+or\$.pg\$	0
Balance	-V#	+DG#		-V\$	+DG\$	0
$\Sigma$	0	0	0	0	0	0

The flow matrix in Table 2 which follows uses the same double entry format to describe all transactions within and between the two economies and defines most of the current price variables which will be used in Model 1.

**Table 2 Flow Matrix for Two Economy Model**

	H'Ids#	Firms#	Govt#		H'Ids\$	Firms\$	Govt\$	
1) Exports		+X#		.xr#		-IM\$		0
2) Imports		-IM#		.xr#		+X\$		0
3) Govt.		+G#	-G#			+G\$	-G\$	0
4) Cons.	-C#	+C#			-C\$	+C\$		0
5) GDP	+Y#	-Y#			+Y\$	-Y\$		0
6) Taxes	-T#		+T#		-T\$		+T\$	0
7) Interest	+B## <sub>-1</sub>		-B## <sub>-1</sub>		+B\$\$ <sub>-1</sub>		-B\$\$ <sub>-1</sub>	0
Changes in:								
8) Money	- $\Delta$ H#		+ $\Delta$ H#		- $\Delta$ H\$		+ $\Delta$ H\$	0
9) Bonds	- $\Delta$ B##.pb#		+ $\Delta$ B##.pb#		- $\Delta$ B\$\$ .pb\$		+ $\Delta$ B\$\$ .pb\$	0
10) Reserves			- $\Delta$ or#.pg#	.xr#			- $\Delta$ or\$.pg\$	0
	0	0	0		0	0	0	0

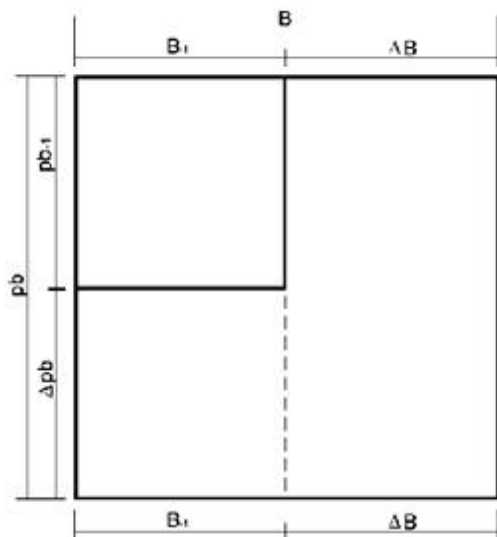
The left half of Table 2 describes the flow transactions of the euro country measured in #s, the right half describes transactions of the dollar country measured in \$s. There are three entries common to both countries, those in rows 1, 2, and 10, and each of these pairs of entries is brought into equivalence by multiplying the entry or the left half by the exchange rate. The top section of Table 2 gives, for each country, the standard components of the national income, except for the drastic simplification that there is no investment in fixed or working capital - an assumption which carries the implication (which the author would normally find highly objectionable) that production instantaneously matches demand regardless of producers' expectations and without any need for fixed or working capital. The middle section of Table 2 describes flows of tax and interest payments. As all bonds are perpetuities, the interest flow is given by the number of bonds outstanding from the previous period, each paying one unit of currency per period. The lower third of the table describes transactions in asset stocks.

It is a feature of Table 2 which may surprise for an instant that neither country has (or needs) a column describing its current balance of payments. However the coherence enforced by double entry accounting ensures that total flows into each country always exactly equal total outflows. Thus trade flows (lines 1 and 2) make up the balance of payments on current account, which is, in turn, exactly equal to the sum of each country's transfers of gold described in line 10. The logic of the double entry system requires that the entries in the final line sum to zero; hence as both entries in line 10 have a negative sign, one country's gold

stock can only rise if the other's falls to an exactly equal extent.

To link the transactions described in Table 2 to the balance sheets in Table 1, it will be necessary to take capital gains into account. The derivation of capital gains can readily be inferred using the following diagram.

**FIGURE 1**



The end-period value of the stock of bonds held in, and issued by, one country is given by the area of the large rectangle, that is by  $B.pb$ . The end-of-previous-period stock is given by the area of the small rectangle,  $B_{-1}.pb_{-1}$ ; hence the change in the value of the stock is given by the sum of the two remaining rectangles.

$$A) B.pb - B_{-1}.pb_{-1} = \Delta B.pb + \Delta pb.B_{-1}$$

The first term on the RHS describes transactions in  $B$ , the second describes the capital gain which occurs when the rate of interest changes.

### THE MODELS

Each model has four interdependent sections - international trade, inflation, income/expenditure determination and asset supplies and demands. The first fifty equations, many of them accounting identities, are, with two exceptions, common to all three models.

### Trade

Trade flows, measured at constant prices, are determined, very conventionally, by relative prices and output at home and abroad, while import and export prices are determined by domestic and foreign inflation rates in combination with the exchange rate.

Noting that capital letters denote variables measured at current prices, lower case denotes constant prices and italics denote logs, the trade volume equations are

$$1) x\# = \epsilon_0 - \epsilon_1(pm\$,_{-1} - py\$,_{-1}) + \epsilon_2 y\$$$

$$2) im\# = \eta_0 - \eta_1(pm\#,_{-1} - py\#,_{-1}) + \eta_2 y\#$$

Equation 1) says that the volume of euro exports ( $x\#$ ) responds with an elasticity of  $\epsilon_1$  with respect to the (dollar) price paid by dollar residents for their imports ( $pm\%$ ) relative to domestic prices ( $py\%$ ) measured in dollars, both lagged one period; and that they respond with an elasticity  $\epsilon_2$  with respect to the real GDP ( $y\%$ ) of the dollar country. Equation 2) says that euro imports ( $im\#$ ) respond with elasticities  $\eta_1$  with respect to import prices ( $pm\#$ ) relative to domestic prices ( $py\#$ ) (both measured in euros) and  $\eta_2$  with respect to domestic output ( $y\#$ ).

Trade prices are assumed to be determined as

$$3) pm\# = \mu_0 - \mu_1.xr + (1 - \mu_1).py\# + \mu_1.py\$ \quad 0 < \mu_1 < 1$$

It is a well established fact that, nowadays at least, import prices do not rise to the full extent of any depreciation of the currency which occurs, probably because exporters shade their prices to maintain market share. A reasonable stylised fact is that the elasticity of the response of import prices to currency depreciation is around 0.7<sup>1</sup>.

If currency depreciation were exactly paralleled by a simultaneous and equal addition to domestic inflation, it is reasonable to expect that import prices would rise by the full amount of the depreciation - hence the coefficient  $(1 - \mu_1)$  on  $py\#$ . The coefficient  $\mu_1$  also describes the effect of foreign inflation because of the presumption that, if euro and dollar domestic prices both rose in the same proportion, with the exchange rate held fixed, import prices would rise by that same proportion as well.

The way euro export prices (i.e. dollar import prices) are determined is symmetrical with 3).

$$4) px\# = <_0 - <_1.xr\# + (1 - <_1).py\# + <_1.py\$ \quad 0 < <_1 < 1$$

These equations imply, logically, what the wholly symmetrical behaviour of dollar export and import volumes and values must be. At constant prices and base year exchange rates (assumed equal to 1),

$$5) : 6) x\$ = im : im\$ = x\$$$

Import and export prices (plus current price flows) for the dollar country also follow by identity.

$$7) : 8) px\$ = px\#.xr\# : pm\$ = pm\#.xr\#$$

$$9) : 10) X\# = x\#.px\# : X\$ = x\$.pm\$$$

$$11) : 12) IM\# = im\#.pm\# : IM\$ = im\$.pm\$$$

The condition, in both countries, for the terms of trade (the ratio of export to import prices) to deteriorate following currency depreciation is that  $v_1 > \mu_1$ . It is worth pointing out, since it is so often assumed that the elasticities with respect to export and import prices must sum to at least one if the trade balance is to improve following devaluation (the Marshall-Lerner condition), that in verify the sum of these elasticities need be no greater than the elasticity of terms of trade with regard to devaluation. For instance, if the deterioration in the terms of trade were one fifth as large as the devaluation, then the sum of elasticities need be no more than 0.2 to get an improvement in the current balance; if there were no change at all in the terms of trade following devaluation - not an unlikely outcome - the sum of the elasticities need be no greater than *positive* for the balance of trade to improve. [Does it need explaining that even if there were no change in the terms of trade following devaluation there would still be an improvement in relative prices for goods traded internationally? E.g. if export and import prices both rose 5% following a 10% devaluation, the relative price of imports (measured in prices of the devaluing country) would (obviously) rise 5% while (only slightly less obviously) the relative price of exports denominated in foreign currency would have fallen 5%.]

### Domestic Prices and Inflation

The volume of sales (s) is given by the identities

$$13) : 14) s\# = c\# + g\# + x\# : s\$ = c\$ + g\$ + x\$$$

where c and g are personal and government consumption.

The price of sales (ps) is assumed to be determined as a mark-up on unit costs

$$15) ps\# = (1 + \Upsilon)(W\#.N\# + IM\#)/s\#$$

$$16) ps\$ = (1 + \Upsilon)(W\$.N\$ + IM\$)/s\$$$

where W describes nominal wage rates and N is employment.

The real wage aspiration  $w^*$  is determined by

$$17) w\#^* = \rho_0 + \rho_1 pr\# + \rho_2 (n\# - n\#^*)$$

$$18) w\$^* = \rho_0 + \rho_1 pr\$ + \rho_2 (n\$ - n\$^*)$$

where  $N\#^*$  and  $N\$^*$  are base year levels of employment assumed to correspond with a neutral level of unemployment, and pr is productivity.

The post-tax nominal wage rate (W) is assumed to follow a first order partial adjustment process

$$19) \Delta W\# = \rho_3 (w\#.pds\#. (1 + \theta\#) - W\#_{-1})$$

$$20) \Delta W\$ = \rho_3 (w\$.pds\$. (1 + \theta\$) - W\$_{-1})$$

where  $\theta$  is the tax rate.

Productivity is assumed to be constant, hence with a suitable choice of units

$$21) N\# = y\#$$

$$22) N\$ = y\$$$

The assumptions regarding costs and prices have a number of accounting corollaries which are essential to complete the model but over which the reader is advised to skim.

The total value of sales (S) is

$$23) : 24) S\# = s\#.ps\# : S\$ = s\$.ps\$$$

The price of domestic sales (pds) and inflation ( $\pi$ ) are given by

$$25) pds\# = (S\# - X\#)/(s\# - x\#)$$

$$26) pds\$ = (S\$ - X\$)/(s\$ - x\$)$$

$$27) : 28) \pi\# = pds\#/pds\#_{-1} - 1 : \pi\$ = pds\$/pds\#_{-1} - 1$$

Domestic output at constant and current prices ( $Y, y$ ), the GDP deflator ( $py$ ), private consumption and government expenditure at current prices are

$$29) : 30) Y\# = S\# - IM\# : Y\$ = S\$ - IM\$$$

$$31) : 32) y\# = s\# - im\# : y\$ = s\$ - im\$$$

$$33) : 34) py\# = Y\#/y\# : py\$ = Y\$/y\$$$

$$35) : 36) C\# = c\#.pds\# : C\$ = c\$.pds\$$$

$$37) : 38) G\# = g\#.pds\# : G\$ = g\$.pds\$$$

### **Income and Expenditure**

Disposable income (YD) is defined so that it is equal to consumption plus the change in the value of wealth (V) so in the model wealth is described as follows.

$$39) : 40) \Delta V\# = YD\# - C\# : \Delta V\$ = YD\$ - C\$$$

As noted in the section on accounting, production is assumed to take place instantaneously in response to demand so it has not, up to this point, been necessary to distinguish the symbols in the behavioural equations from those in the accounting matrices. From now on however, the way in which equivalence between supply and demand is achieved will be central to the argument. Accordingly the subscript s or d, denoting supply or demand, will be attached wherever appropriate.

The definitions in 39) and 40) imply that disposable income consists of factor income plus interest payments less taxes (T) plus capital gains.

$$41) YD\# = Y\# + B\#\#_{s-1} - T\# + \Delta pb\#.B\#\#_{s-1}$$

$$42) YD\$ = Y\$ + B\#\$\$_{s-1} - T\$ + \Delta pb\$.B\#\$\$_{s-1}$$

The final term in both these expressions, which describes capital gains, was explained in equation A) in the accounting section at the beginning.

Taxes are levied on factor income plus interest flows.

$$43) T\# = \theta\#.(Y\# + B\#\#_{s-1})$$

$$44) T\$ = \theta\#.(Y\$ + B\#\$\$_{s-1})$$

Real personal disposable income (yd) is defined so that it equals real consumption plus the change in the real stock of wealth so

$$45) yd\# = YD\#/pds\# - v\#_{-1}.\pi\#/(1 + \pi\#)$$

$$46) yd\$ = YD\$/pds\$ - v\#_{-1}.\pi\#/(1 + \pi\$)$$

where the real stock of wealth is

$$47) : 48) v\# = V\#/pds\# : v\$ = V\$/pds\$$$

implying that real income less real consumption equals the change in the real stock of wealth

$$48a) \Delta v = yd - c$$

The consumption function is

$$49) : 50) c^{\#} = \alpha_1 \cdot yd^{\#} + \alpha_2 \cdot v^{\#}_{-1} : c^{\$} = \alpha_1 \cdot yd^{\$} + \alpha_2 \cdot v^{\$}_{-1}$$

Equations 45)- 50) imply that the consumption function is also a wealth adjustment process described by 50a)

$$50a) \Delta v = \alpha_2 (yd \cdot (1 - \alpha_1) / \alpha_2 - v_{-1})$$

from which it follows that the real stock of wealth will tend to converge towards

$$50B) v^* = yd^* (1 - \alpha_1) / \alpha_2$$

where the stars denotes steady state values.

### ASSET SUPPLIES AND DEMANDS (MODEL 1)

The asset demand functions for the euro country are

$$51) B^{\#}_{d.pb^{\#}} = V^{\#} (\lambda_{01} + \lambda_{11} r b^{\#} + \lambda_{31} \pi^{\#})$$

$$52A) H^{\#}_{d} = V^{\#} (\lambda_{03} - \lambda_{13} r b^{\#} - \lambda_{33} \pi^{\#})$$

For the dollar country they are

$$53) B^{\$}_{d.pb^{\$}} = V^{\$} (\lambda_{01} + \lambda_{11} r b^{\$} + \lambda_{31} \pi^{\$})$$

$$54A) H^{\$}_{d} = V^{\$} (\lambda_{03} - \lambda_{13} r b^{\$} - \lambda_{33} \pi^{\$})$$

Tobin-Brainard constraints (more fully described in Model 2) are assumed to hold - that is the sum of constants is equal to one while the sum of the other columns is zero.

As wealth has already been determined in 39) and 40) equations 52A) and 54A) are formally redundant since they are implied by other equations in the model. Accordingly, the demand for money is *modelled* as a residual although it is *determined* behaviourally in 52A) and 54A) and motivated in essentially the same way as other asset demands

$$52) H^{\#}_{d} = V^{\#} - B^{\#}_{d.pb^{\#}}$$

$$54) H^{\$}_{d} = V^{\$} - B^{\$}_{d.pb^{\$}}$$

The two government budget constraint equations are

$$55) \Delta or^{\#}.pg^{\#} = T^{\#} + \Delta B^{\#}_{s.pb^{\#}} - G^{\#} - B^{\#}_{s-1}$$

$$56) \Delta or^{\$}.pg^{\$} = T^{\$} + \Delta B^{\$}_{s.pb^{\$}} - G^{\$} - B^{\$}_{s-1}$$

Finally, the fact that interest rates are determined exogenously means that the government supplies bonds for cash passively, given those interest rates.

$$57) : 58) H^{\#}_{s} = H^{\#}_{d} : H^{\$}_{s} = H^{\$}_{d}$$

$$59) : 60) B^{\#}_{s} = B^{\#}_{d} : B^{\$}_{s} = B^{\$}_{d}$$

The price of gold (pg) is related to the exchange rate by the identities

$$61) : 62) : 63) pg^{\#} = 1/xr^{\#} : pg^{\$} = 1/xr^{\$} : xr^{\$} = 1/xr^{\#}$$

The model is now complete. Its exogenous variables are government expenditure in each country, the two tax and interest rates and the exchange rate. Every other variable has its equation except for the "missing" equation - the one which makes the LHS variables of the two government budget equations equal - and therefore which makes a gain in one country's gold stock equal to the gold loss of the other country. But this equation

$$64) \Delta or^{\#}.pg^{\#} = - \Delta or^{\$}.pg^{\$}.xr^{\$}$$

although it is not included explicitly in the model is found to be satisfied when the model is solved numerically.

With one exception, there is nothing surprising about the simulation results which this model yields. It is pretty obvious that balance of payments surpluses and deficits will always exactly equal changes in gold reserves - the only capital account transaction available. So long as the exchange rate, interest rates and fiscal policy are held constant, there is no mechanism which corrects an emergent deficit in the balance of payments except to the extent that the foreign trade multiplier reduces domestic output so that imports fall; there is simply a drop in reserves which continues until they run out. An emerging deficit can be corrected by fiscal disinflation or, temporarily, by a rise in interest rates, the effects of which work entirely by reducing real output and thereby imports. A deficit can also be corrected (at some cost in terms of inflation) by depreciating the currency, which is the same thing as raising the price of gold.

The interesting thing to emerge is that although a deficit country loses gold reserves, this loss has no independent effect on anything else at all; there is, in particular, no vestige whatever of a "price-specie-flow" mechanism. No "sterilisation" process needs to, or can, occur. An emergent deficit, as already mentioned, reduces real output and therefore (to some extent) the demand for imports and the rate of inflation. But there is no other feedback mechanism. Gold is flowing out of the country sure enough, but this leaves households' wealth accumulation completely unaffected (except to the extent that incomes are reduced) while assets are supplied, at given interest rates, on demand and in exactly in the right proportions, by 57) - 60). *The number of equations and unknowns in the model is such that there is no way to describe asset supplies other than as passive responses to demands.*

**MODEL 2**

Model 2 allows free capital movements but keeps the exchange rate exogenous. The inclusion of asset transactions requires an expanded system of concepts which are set forth in two new accounting matrices.

Table 4 on the next sheet gives the expanded transactions matrix which describes the accounting relationships between nominal variables in Model 2.

Table 3 Balance sheets of the expanded model

	H'Ids	Govt.	Bank		H'Ids	Govt.\$	Bank	
Money	+H#		-H#		+H\$		-H\$	0
#Bonds	+B##.pb#	-B##.pb#						0
		-B\$#.pb#		.xr#	+B\$#.pb#.xr#			0
\$Bonds					+B\$\$ .pb\$	-B\$\$ .pb\$		0
	+B#\$ .pb\$.xr\$			.xr#		-B#\$ .pb\$.		0
Bills		-BS#	+BS#			-BS\$	+BS#	0
Reserves			+or#.pg#	.xr#			+or\$.pg\$	0
Balance	-V#	+DG#	0	.xr#	-V\$	+DG\$	0	0

As Table 3 shows, the conceptual framework has been expanded to include central banks whose balance sheet is familiar, in amputated form, from a thousand textbooks. It also shows stocks of each country's bonds held by residents of the other. Table 4 Expanded flow matrix for Model 2

	H'lds#	Firms#	Govt#	Bank#		H'lds\$	Firms\$	Govt\$	Bank\$	
1) Exports		+X#			.xr#		-IM\$			0
2) Imports		-IM#			.xr#		+X\$			0
3) Govt.		+G#	-G#				+G\$	-G\$		0
4) Cons.	-C#	+C#				-C	+C\$			0
5) GDP	+Y#	-Y#				+Y\$	-Y\$			0
6) Taxes	-T#		+T#			-T\$		+T\$		0
7) Interest on : # bonds held# (\$\$, \$\$)	+B## <sub>-1</sub>		-B## <sub>-1</sub>			+B\$\$ <sub>-1</sub>	-B\$\$ <sub>-1</sub>			0
8) # bonds held \$			-B\$\$ <sub>-1</sub>		.xr#	+B\$\$ <sub>-1</sub> .xr #				0
9) \$ bonds held #	+B\$\$ <sub>-1</sub> .xr\$				.xr#			B\$\$ <sub>-1</sub>		0
Changes in:										
10) money	-ΔH#			+ΔH#		-ΔH\$			+ΔH\$	0
11) # bonds held # (\$\$, \$\$)	-ΔB##.pb#		+ΔB##.pb#			-ΔB\$\$ .pb\$		+ΔB\$\$ .pb\$		0
12) # bonds held \$			+ΔB\$\$ .pb#		.xr#	ΔB\$\$s.pb#.xr#				0
13) \$ bonds held #	-ΔB\$\$ .pb\$.xr\$				.xr#			+ΔB\$\$ .pb\$		0
14) Bills			+ΔBS#	-ΔBS#				+ΔBS\$	-ΔBS\$	0
15) Reserves				+Δor#.pb#	.xr#				-Δor\$.pb\$	0
	0	0	0	0		0	0	0	0	0

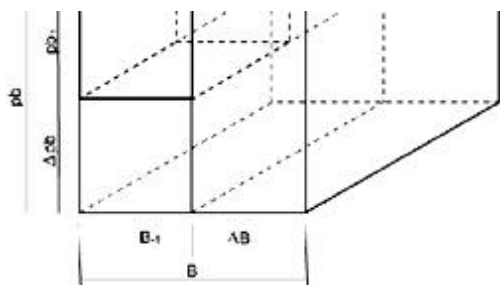
The derivation of capital gains is slightly more complex than in Model 1 as some of the stock variables are now the product of three terms. A graphical exposition is perhaps again the simplest.

**FIGURE 2**



The end period value of the stock of the bonds held at home but issued abroad is given by  $B.pb.xr$  which is represented in the figure by the volume of the big box. The end-of-previous- period stock is given by the smaller box,  $B._1.pb._1.xr._1$ . The difference between these two boxes is given by the sum of the three remaining boxes viz.





$$B) B.pb.xr - B_{-1}.pb_{-1}.xr_{-1} = \Delta B.pb.xr + \Delta xr.B_{-1}.pb_{-1} + \Delta pb.xr.B_{-1}.$$

The first of the three terms on the RHS of B) describes transactions, the other two describe capital gains arising from changes in exchange rates and interest rates.

Before picking up the Model 2 story from where we left Model 1 at 50) we need to revise the definitions of disposable income implied by 39) and 40) - also the tax function - to incorporate the larger number of assets. Disposable income, using the accounting equation B) above as well as A), is given by

$$41B) YD\# = Y\# + B\#\#_{s-1} + xr\$.B\#\$_{s-1} - T\#$$

$$+ \Delta xr\$.B\#\$_{s-1}.pb\$ + \Delta pb\$.xr\$.B\#\$_{s-1} + \Delta pb\#.B\#\#_{s-1}$$

$$42B) YD\$ = Y\$ + B\#\$_{s-1} + xr\#.B\#\#_{s-1} - T\$$$

$$+ \Delta xr\#.B\#\#_{s-1}.pb\# + \Delta pb\#.xr\#.B\#\#_{s-1} + \Delta pb\$.B\#\$_{s-1}$$

Taxes are levied on factor income and interest flows.

$$43B) T\# = \theta\#.(Y\# + B\#\#_{s-1} + xr\$.B\#\$_{s-1})$$

$$44B) T\$ = \theta\$. (Y\$ + B\#\$_{s-1} + xr\#.B\#\#_{s-1})$$

Model 2 requires equations describing the transactions of each central bank. [At this point the equation numbering proceeds from where we ended Model 1]

$$65) \Delta BS\#_d = \Delta H\#_s - \Delta or\#.pg\#$$

$$66) \Delta BS\$_d = \Delta H\$_s - \Delta or\$.pg\$$$

where BS describes short term bills which do not pay interest and are assumed to be held only by the central bank.

We can now write the flow supplies of financial assets given by the two government budget constraint equations

$$67) \Delta B\#\#_s.pb\# = G\# + B\#\#_s + B\#\#_s - T\#$$

$$+ \Delta B\#\#_s.pb\# + \Delta BS\#_s$$

$$68) \Delta B\#\$_s.pb\$ = G\$ + B\#\$_s + B\#\#_s - T\$$$

$$+ \Delta B\#\$_s.pb\$ + \Delta BS\$_s$$

Now that households can buy foreign as well as domestic bonds, the expanded array of asset demands, for the euro country, is

$$69) B\#\#_d.pb\# = V\#(0_1 + 8_{11}rb\# - 8_{21}rb\$ + 8_{31}\pi\#)$$

$$70) B\#\$_d.pb\$ = V\#(8_{02} - 8_{12}rb\# + 8_{22}rb\$ + 8_{32}\pi\#)$$

$$71a) H\#_d = V\#(8_{03} - 8_{13}rb\# - 8_{23}rb\$ - 8_{33}\pi\#)$$

For the dollar country it is

$$72) B\#\$_d.pb\$ = V\$(\lambda_{01} + \lambda_{11}rb\$ - \lambda_{21}rb\# + \lambda_{31}\pi\$)$$

$$73) B\#\#_d.pb\# = V\$(\lambda_{02} - \lambda_{12}rb\$ + \lambda_{22}rb\# + \lambda_{32}\pi\$)$$

$$74a) H\$_d = V\$(\lambda_{03} - \lambda_{13}rb\$ - \lambda_{23}rb\# - \lambda_{33}\pi\$)$$

As with Model 1, the sum of the "constants" for each block is unity, while the sum of all other columns is zero. However, it cannot be too strongly emphasised that while, for any given solution of the model, the parameters must add up in this way, this does not mean that they remain constant through time. On the contrary, the parameters and "constants" will be in a continuous state of flux as circumstances, and particularly expectations, change.

As in model 1, the demand for money is modelled as a residual although it is determined behaviourally in 54A) and 57A), motivated in essentially the same way as other asset demands

$$71) H\#_d = V\# - B\#\#_d.pb\# - B\#\$_d.pb\$\$$

$$74) H\$_d = V\$_ - B\#\$_d.pb\# - B\#\#_d.pb\#$$

It remains to write down equations describing asset supplies and equilibrating conditions.

The central bank exchanges money for bonds on demand to households at given rates of interest

$$75): 76) H\#_s = H\#_d : H\$_s = H\$_d$$

The government exchanges bills on demand to the central bank according to its requirements arising from changes in the demand for money and its dealings in gold.

$$77): 78) BS\#_s = BS\#_d : BS\$_s = BS\$_d$$

We now need an equation linking changes in gold reserves by one country to changes in gold reserves in the other country; these changes must obviously be equal and have opposite signs - and only one can be exogenous.

$$79) \Delta or\$.pg\$\ = -\Delta or\#.pg\#.xr\#$$

The government has no means of determining how its issue of bonds is going to be split between foreign and domestic purchasers. So these supplies are written as automatic responses to demands

$$80) : 81) B\#\#_s = B\#\#_d.xr\# : B\#\$_s = B\#\$_d.xr\$\$$

We have now reached a point of central importance. Model 2 as so far written is over-determined, with equations in both  $B\#\$_d$  and  $B\#\$_s$  and also in both  $B\#\#_d$  and  $B\#\#_s$ . One of these pairs - let it be the first - can (indeed must) be explained by making it the missing equation which will be satisfied by virtue of the model's watertight accounting, without including it explicitly as an equation in the model. So far as the second pair goes, there is only one solution to the problem of over-determination - to write the equivalence as an equilibrium condition

$$82) B\#\#_d = B\#\#_s$$

*in which case equation 69) has to become an equation in the euro rate of interest.* Treating as exogenous fiscal policy, dealings in gold by one central bank - assumed to be acceptable to the other - and the exchange rate, only a single interest rate can remain exogenous. *Given fiscal policy, in a world where there is free movement of capital as well as free trade, one interest has to be endogenous,* determined by supply and demand in asset markets and, in the last resort, in defiance of arbitrage conditions. This is to say that the model is fundamentally non self righting; it is formally unstable, as simulation experiments very quickly and dramatically reveal.

There is one simulation experiment (suggested to me in conversation by Jan Kregel), which is worth reporting both because of its intrinsic interest and because it illustrates the kind of results that may be obtained using this method.

Suppose you have a country (I imagine a Latin American country) trying to keep its exchange rate fixed at a time when it has a rate of inflation which substantially exceeds that of its trading (and investing) partners. Model 2 provides strong grounds for concluding that (in the absence of fiscal restriction) there will be a progressive rise in that country's nominal bond rate of interest. Now suppose that the increased interest differential has the effect of making the bonds in question more desirable to international investors so that they discontinuously buy more "Brazilian" bonds. The very high nominal interest rate will bring a handsome return to international investors for as long as the exchange rate is held fixed. Moreover the very fact that foreign capital is pouring in means that the interest rise is (for a time) checked so that crisis is postponed. Meanwhile, however, the economy declines and the current balance of payments deteriorates.

### MODEL 3

Model 2 can be rearranged to endogenise exchange rates very simply by rearranging the budget constraint 67) to be an equation in the supply of assets abroad

$$67a) \Delta B_{\$s, pb} = G + B_{\$s} + B_{\$s} - T$$

$$+ \Delta B_{\$s, pb} + \Delta B_{\$s}$$

The equilibrium condition 82) reverts to being a passive supply

$$82a) B_{\$s} = B_{\$d}$$

And the exchange rate now emerges as a simple implication of everything that has gone before.

$$83) xr = B_{\$d}/B_{\$s}$$

If governments determine fiscal policy and their own interest rates independently, and if they do not deal in reserve assets, there is no escaping the fact that, in the short term, the exchange rate will float in response to demand and supply in asset markets over which governments have no direct control. As was the case in Model 2 with its endogenous interest rate, we now have an endogenous exchange rate which will be determined as much by supplies of assets (determined, in turn, by what is happening to trade balances and government finances) as by demand.

The model just described is stable. Corresponding to any combination of exogenous (policy) settings both economies settle into steady states where the real (inflation accounted) balance of payments is zero and the real stock of wealth is in its long run relationship to disposable income. Within the limits imposed by the inflationary consequences of any configuration of policies, governments *can* achieve the levels of activity at which they aim by an appropriate choice of fiscal policy. The last proposition must be heavily qualified because an alternative form could plausibly be given to the wage equation which would cause inflation to explode following any attempt by governments to increase activity in its economy.

Finally if we make the assumption that a change in expectations alters the relative demand for one country's assets e.g. by raising  $\lambda_{02}$  and reducing  $\lambda_{01}$  in equations 72) and 73), the effect on the exchange rate, though it may be large and immediate, is essentially self reversing because of the feedback from trade, though the re-achievement of "equilibrium" may take a long time. Hence, while hardly anything has been said about expectations in this paper, I incline to the view that their role (though very important) is somewhat exaggerated in much contemporary discussion of exchange rate theory.

My main objective has been just to lay down a very basic alternative foundation for open economy macro. Beyond exploring the properties of these models in greater detail, the next stage of the work (already far advanced) will be to design a more elaborate financial system (which will include commercial banks) plus domestic and foreign investment etc.

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