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by Francesco Papadia and Salvatore Rossi

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The purpose of the «Temi di discussione» series is to promote the circulation of working papers prepared within the Bank of Italy or presented in Bank seminars by outside economists with the aim of stimulating comments and suggestions.

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In the seventies, a number of industrial countries made recourse to asymmetric exchange controls, i.e., to administrative measures aimed at restraining outflows of domestic capital. During the eighties, a process of liberalization was underway and the issue arose of its macroeconomic impact. In this paper we analyze asymmetric exchange controls with different hypotheses regarding three key aspects: (i) the domestic policy mix; (ii) the degree of substitutability between domestic and foreign assets; (iii) the financial size of the economy. We find that the macroeconomic effectiveness of exchange controls is reduced, at the limit to nothing: (i) as the country concerned follows a strict monetary policy or a lax fiscal policy; (ii) as domestic and foreign assets tend to be perfect substitutes; (iii) as the domestic economy represents a small segment of an integrated (but for controls) financial market.

1 - Introduction (*)

In the seventies, a number of industrial countries made recourse to administrative measures in order to restrain outflows of domestic capital. It was a way to "lock in national savings and create room for a systematically divergent course in (domestic) financial policies".[1] The movements, in and out, of capital owned by foreigners were left, instead, basically free. This "asymmetry" in exchange controls was justified on the grounds that "any hindrance to this freedom, by making domestic assets less desirable for international investors, would have contradicted the goal of increasing domestically available resources".[2]

During the eighties, a general process of exchange liberalization was underway. In the EEC, the final move will be made in 1990, with the abolition of the residual restrictions on short-term capital flows. However, the EEC directives[3] admit that, in particular circumstances, temporary exchange controls may still be introduced, which would share with the constraints applied in the past the characteristic of asimmetry, in the sense specified above.

In this paper, we analyze the macroeconomic effectiveness of asymmetric exchange controls, with different hypotheses regarding three key aspects: i) the domestic policy mix, ii) the degree of substitutability between domestic and foreign assets, iii) the financial size of the economy.

In Section I we deal with the first aspect, using a framework à-la-Dornbusch (1976). In Section II the second and the third aspect are taken into account with a model including demand functions for domestic and foreign assets by residents and non-residents. Section III contains some concluding remarks.

2 - Exchange Controls and the Policy Mix

It has been recently argued that the administrative controls on capital outflows in force in Italy through the eighties were essentially redundant, because the policy mix prevailing since the beginning of the decade has been one of tight monetary policy and easy fiscal policy, that per se encourages net capital inflows. The proposition has been proved in a Mundell-Fleming analytical framework with both fixed and flexible exchange rates.[4] The same conclusion, however, can also be reached in a model à-la-Dornbusch, displaying such features as a slowly adjusting goods market, rational expectations and an exchange rate which immediately jumps to its short-term equilibrium level, following a shock, moving then over time to its steady-state value (such a model can be interpreted as approximating a regime of pegged exchange rates with realignments). The model is fully developed in the Appendix.

Fig. 1

Monetary contraction

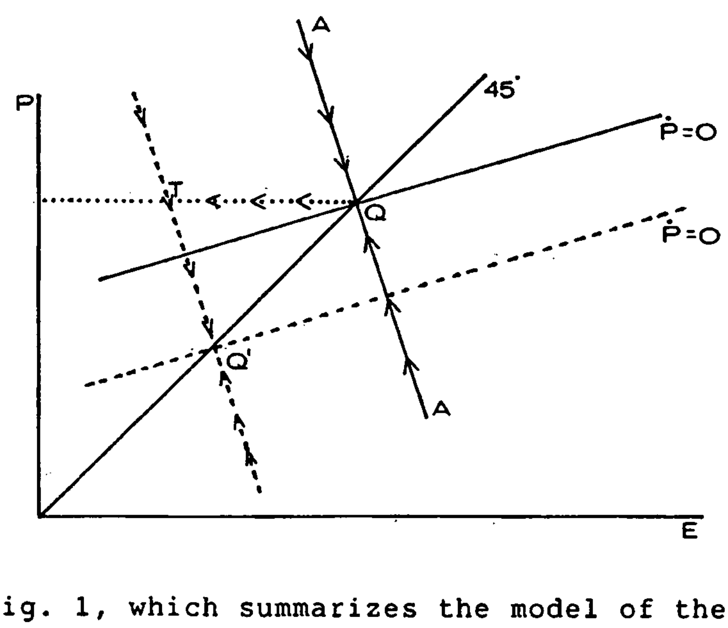

Fig. 1, which summarizes the model of the Appendix, reproduces, in the domestic price (P) - exchange rate (E) space, the classical, 1976 Dornbusch result: AA represents the equilibrium on the foreign exchange market while the $\dot{P}=0$ line represents equilibrium on the goods market. A <u>monetary contraction</u> shifts the $\dot{P}=0$ line downwards and the AA line to the left. Long-run equilibrium moves from Q to Q'. The path displays the overshooting pattern: the exchange rate appreciates instantly to T; the price level remains initially unchanged and only gradually moves down to Q'; until the new equilibrium is reached, competitiveness deteriorates. This implies a current account deficit which has to be financed through capital inflows.

Thus, a monetary contraction induces domestic residents to borrow abroad, and makes them net foreign debtors. In any period after the shock, net exports are negative, though converging back to equilibrium, since the real exchange rate remains appreciated with respect to the situation prevailing before the shock. In addition, interest payments on the preexisting stock of foreign debt add to the deficit, which has to be financed by borrowing abroad. As a result, the foreign debt keeps growing, even in steady-state (of course, this raises a problem of sustainability, on which we shall say a few words later). Hence, asymmetric exchange controls would never get binding.

<u>Fig. 2</u>

Fiscal expansion

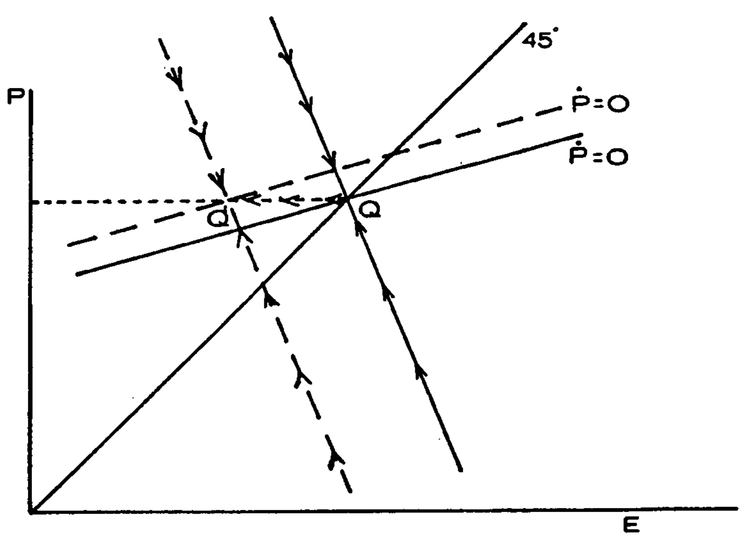

Figure 2 illustrates the case where the shock imparted to the system is of a fiscal nature. A permanent, unanticipated fiscal expansion causes a once-and-for-all appreciation of the exchange rate (from Q to Q'). This crowds out net exports, so that no excess demand is left and prices do not change.

This combination of results permanently deteriorates competitiveness. The effect on capital movements is of the same nature as in the case of a monetary restriction: a permanent current deficit, causing an increasing foreign debt. In this case again, controls on capital outflows would remain redundant.

In conclusion, a policy mix of monetary contraction and/or fiscal expansion brings about an appreciation of the exchange rate, a deficit on the current account and compensating capital inflows. Thus, the country becomes a capital importer and asymmetric controls in the outflow direction are redundant.

More generally, it is confirmed that there must be consistency between the policy mix and the direction in which capital controls are applied, for them to be effective. If a policy mix of monetary ease and/or fiscal stringency is pursued, the domestic interest rate can be further lowered by means of controls on capital outflows; viceversa, with a policy mix of monetary stringency and/or fiscal ease, the domestic interest rate can be further hightened by means of controls on capital inflows.

We noted before that the external debt grows without bounds in the case of both a monetary restrictive impulse and a fiscal expansive shock, engendering a sustainability problem. If, in the model of the Appendix, we had a balance sheet for the public sector, we would also see, for the same reason, public debt growing explosively, if the rate of interest was higher than the rate of growth of the economy.

The model fortunately provides a very simple test of sustainability. If the public perceived the situation to be unsustainable, it would come to expect sometimes in the future a reversal of the policy mix, with monetary policy becoming lax and/or fiscal policy becoming restrictive. However, the forward-looking nature of the model would anticipate the effects of any such reversal and cause an immediate depreciation of the exchange rate and a decrease in net foreign indebtness, eventually leading to the acquisition of net foreign assets abroad and the actual imposition of the tax on interest income. If nothing like this happens, a stable situation must somehow be expected by the public.[5]

In economic policy terms, if policies of monetary restriction and fiscal expansion have their normal effect of appreciating the exchange rate, thereby reducing net exports and net foreign assets, the situation can be deemed sustainable and exchange controls on outflows redundant.

3 - Exchange Controls, Asset Substitutability and the Financial Size of the Economy

In a scheme à-la-Dornbusch, domestic and foreign assets are supposed to be perfect substitutes (given a premium to offset anticipated exchange rate changes), while the country concerned is assumed "small" in the world capital market, so that it faces a given interest rate abroad.

In this paragraph, we shall relax these limiting assumptions, presenting a model in which both the degree of asset substitutability and the (relative) size of the domestic economy are parameters. In addition, in order to better approximate the functioning of the European Monetary System, we shall assume fixed exchange rates.

We shall use a constant-prices, portfolio-balance model, where only the financial block of the economy is considered and the dynamics is given by the savings-wealth circuit[6] (time subscripts are omitted; subscripts denote partial derivatives):[7]

(1) $M = Wm(R,i)$, $-m_1 = -m_2 = \mu > 0$,

(2) $B = Wb(R,i)$, $b_1 = -b_2 = \beta > 0$,

(3) $F = Wf(R,i)$, $f_1 < 0,\ f_2 > 0$,

(4) $i = R^*(1-\tau)$, $0 \leq \tau \leq 1$,

(5) $B^* = W^* b^*(R,R^*)$, $b_1^* = -b_2^* = \beta^* > 0$,

(6) $M = \tilde{M}B + MF$,

(7) $B + \tilde{M}B + B^* = \tilde{B}$,

(8) $W = \int_0^t S dt$,

(9) $S = S(R,i,W)$, $S_1 = S_2 > 0,\ S_3 < 0$.

Equations (1), (2) and (3) define, respectively, the demand for money, domestic (government) bonds and foreign bonds by residents, as functions of the domestic interest rate (R) and the after-tax foreign interest rate (i), with wealth (W) as a scale variable. We shall assume that the partial derivatives of the three demand functions with respect to the interest rates are such:

$$(10) \qquad m_1 + b_1 + f_1 = m_2 + b_2 + f_2 = 0,$$

that the wealth constraint is always respected: $m+b+f = 1$.

Note that domestic and foreign assets are imperfect substitutes, since b_2, f_1 and b_2^* are finite values. Equation (4) defines the after-tax foreign interest rate: it incorporates exchange controls as a tax on income from foreign bonds. Equation (5) states that the foreign demand for domestic bonds is a function of interest rates, scaled by foreign wealth (W^*, assumed invariant). Asymmetry appears in this model through the fact that non-residents are not subject to the tax.

Equation (6) is the balance sheet of the central bank, where the counterparts of money are domestic ($\tilde{MB}$)[8] and foreign (MF) bonds. $\tilde{MB}$ is the monetary policy parameter, while MF represent foreign exchange reserves. Equation (7) gives the equilibrium on the domestic bond market, where the total supply of government bonds ($\tilde{B}$) is the fiscal policy parameter. Equation (8) defines domestic wealth as the cumulation of savings.[9] Equation (9) puts savings by residents as a function of interest rates and domestic wealth.

The model has three instrumental variables ($\tilde{MB}$, $\tilde{B}$, and τ) and two exogenous variables: W^* and R^*. In order to formally remove the "small country" assumption, R^* should be made endogenous.[10] However, this would imply heavy calculations without substantially improving the understanding of the economics of the model. Therefore, we shall keep R^* exogenous (thus retaining the assumption that the domestic economy is "small"), while varying the parameter W^* to consider different degrees of "smallness" of the home economy with respect to the rest of the world.

If we substitute (2) and (5) into (7), we have:

$$(11)\quad Wb + W^*b^* + \tilde{MB} = \tilde{B} \ ,$$

while the stationary state condition is:

$$(12)\quad \frac{dW}{dt} = S = 0.$$

Equations (11) and (12) can be used to determine the steady-state effect of an increase in the foreign interest rate <u>on the domestic interest rate</u>, in the presence of asymmetric controls.[11] The emphasis on the movements of the interest rate abroad, as the exogenous disturbance whose effects we want to examine, is warranted on two grounds: firstly, it can shed some light on the issue of the necessary amount of interest rate co-ordination in a system like the EMS with and without exchange controls; secondly, it can illustrate the problem of exogenous shifts in exchange rate expectations, if the foreign interest rate is interpreted as including the expected rate of re/devaluation.

Taking the total differential of equation (11), substituting into it the differential of (12), assuming that controls did not exist ($\tau = 0$) prior to the shock and that they are imposed at a rate which just eliminates the incentive to replace domestic assets with foreign ones ($d\tau = dR^*/R^*$), noting that at any point in time domestic wealth is a predetermined variable, we have:

$$(13) \quad dR\Big|_c = \frac{d\tilde{B} - d\tilde{M}B + |B_2^*|\, dR^*}{B_1^* + B_1 + \alpha b} > 0 ,$$

where:

$$\alpha = -\frac{S_1}{S_3} > 0.$$

With exchange controls, an increase in the foreign interest rate does determine, in the steady state, an increase in the domestic one, but only to an extent which depends on the reaction of non-residents on the domestic bond market ($|B_2^*|$).

Without controls (i.e. with $\tau = 0$, $d\tau = 0$) we have instead:

$$(14) \quad dR\Big|_n = \frac{d\tilde{B} - d\tilde{M}B + \left(|B_2^*| - \alpha b + |B_2|\right) dR^*}{B_1^* + B_1 + \alpha b} > 0 .$$ [12]

In this case, the (positive) effect of an increase in the foreign interest rate on the domestic one is greater than with capital controls, because it also depends on the reaction of residents on the domestic market (B_2), which was neutralized in equation (13) by capital controls.

Now, if we assume that there is no policy response, either fiscal or monetary, to the shock ($d\tilde{B} = d\widetilde{MB} = 0$) and normalize domestic wealth at 1 ($W = 1$), equations (13) and (14) can be simplified as follows:

$$(15) \quad \left.\frac{dR}{dR^*}\right|_c = \frac{W^*\beta^*}{W^*\beta^* + \beta + \alpha b} ,$$

$$(16) \quad \left.\frac{dR}{dR^*}\right|_n = \frac{W^*\beta^* + \beta - \alpha b}{W^*\beta^* + \beta + \alpha b}$$

Note that the parameters β^* and $1/W^*$ represent, respectively, the sensitivity of the non-residents' asset demand to interest rates (thus, it also represents the degree of substitutability with foreign assets that foreigners attach to domestic bonds) and the relative size of the domestic financial market.

The steady-state effectiveness of exchange controls, in dampening the fluctuations of the domestic interest rate induced by external financial shocks, is measured by:

$$\left.\frac{dR}{dR^*}\right|_n - \left.\frac{dR}{dR^*}\right|_c = \frac{\beta - \alpha b}{W^*\beta^* + \beta + \alpha b}$$

This is an inverse function of both W^* and β^*. At the limit, it vanishes (and dR/dR^* becomes unitary with or without controls) as domestic and fcreign assets tend to become perfect substitutes in the view of non-residents ($\beta^* \to \infty$) or the size of the world capital market tends to become infinite relative to the domestic market ($W^* \to \infty$).

Notice that in a structural model β^*, the degree of substitutability between domestic and foreign bonds for non-residents, would be derived endogenously. For instance, it could be made dependent on the stability (credibility) of the domestic monetary policy. At the limit, if $\beta^* = 0$, exchange controls would matter, reducing the impact of foreign shocks on domestic interest rates irrespective of the relative size of the domestic economy.

Let us now analyze the short-run effects of the shock. The impact multipliers (denoted by the operator D) are:

$$(17)\quad \left.\frac{DR}{DR^*}\right|_c = \frac{W^*}{1 + W^*} \,,$$

$$(18)\quad \left.\frac{DR}{DR^*}\right|_n = 1.$$

Here we see that the degree of asset substitutability does not play any role. With or without controls, the impact only depends on the relative size of the economy. At the limit, it is:

$$\lim_{W^* \to \infty} \left.\frac{DR}{DR^*}\right|_c = 1$$

and, again, controls are totally ineffective.

The analysis of the effects of a financial shock from abroad <u>on official exchange reserves</u> leads to conclusions which are only slightly different from those applying to the domestic interest rate.

Starting with the steady state, let us substitute (1) into (6), and differentiate totally under the steady-state constraint of equation (12); we have:

$$(19)\quad (dMF + d\tilde{M}B)\Big|_c = (M_1 + \alpha m)\, dR \,,$$

$$(20)\quad (dMF + d\tilde{M}B)\Big|_n = (M_1 + \alpha m)\,(dR + dR^*)\ ,$$

which simply say that if there is a change in interest rates the demand for money will react and the balance-sheet constraint of the central bank will require a matching change in its foreign (dMF) or domestic ($d\tilde{M}B$) assets. If we assume $d\tilde{M}B = 0$, i.e. no change in monetary policy, and substitute for dR from equations (15) and (16) while retaining all the assumptions previously made, we have:

$$(21)\quad \frac{dMF}{dR^*}\Big|_c = (\alpha m - \mu)\ \frac{W^*\beta^*}{W^*\beta^*+\beta+\alpha b} < 0\ ,$$ [13]

$$(22)\quad \frac{dMF}{dR^*}\Big|_n = (\alpha m - \mu)\left(\frac{2W^*\beta^*+2\beta}{W^*\beta^*+\alpha b+\beta}\right) < 0\ .$$

Thus, an increase in the foreign interest rate causes, in the steady state, with and without controls, a decrease in official reserves. However, reserves are less reactive to the external shock when exchange controls are in force. In fact, controls have a double effect on the demand for money of residents, and therefore on the assets of the central bank; firstly, a direct effect: the after-tax foreign rate (denoted as i) is kept constant as the gross rate (R^*) moves; secondly, an indirect effect: as we have seen above, controls reduce the change in the domestic interest rate following the shock in the foreign one.

As in the previous case, we can measure the steady-state effectiveness of exchange controls in protecting official reserves from external financial shocks, by:

$$\Delta = \left| \left.\frac{dMF}{dR*}\right|_n - \left.\frac{dMF}{dR*}\right|_c \right| = |\alpha m - \mu| \frac{W^* \beta^* + 2\beta}{W^* \beta^* + \beta + \alpha b} .$$

It is:[14]

$$\lim_{\beta^* \to \infty} \Delta = \lim_{W^* \to \infty} \Delta = |\alpha m - \mu| < \Delta .$$

Hence, the effectiveness of controls is minimized (though not totally eliminated) as domestic and foreign assets tend to become perfect substitutes and the relative size of the domestic economy gets smaller and smaller. Notice, however, that the protecting effect of exchange controls crucially depends on the presence of the foreign interest rate (net of taxes) in the residents' demand for money function. Should we exclude this argument and make money demand entirely dependent on the domestic alternative yield (as in Branson and Henderson, 1985), exchange controls would result redundant.

Finally, let us calculate the impact multipliers. Recalling eqq. (21) and (22) we have:

$$(23) \quad \left.\frac{DMF}{DR^*}\right|_c = - \mu \frac{W^*}{W^*+1}$$

and:

$$(24) \quad \left.\frac{DMF}{DR^*}\right|_n = - 2\mu .$$

We can note that, as in the case of the domestic interest rate, the degree of asset substitutability has no influenceB[B in the short term. Exchange controls reduce the impact of the shock on reserves even if the relative size of the economy is very small:

$$\lim_{W^* \to \infty} \left. \frac{DMF}{DR^*} \right|_c = -\mu \, .$$

However, this, again, depends on the presence of the foreign rate of interest in the demand for money of residents.

4 - Conclusions

The effectiveness of exchange controls is an issue of some economic policy relevance. In particular, the effect of their abolition on the cohesiveness of the EMS has been hotly debated, with a few authors expecting dramatic consequences (Basevi and Cavazzuti, 1985; Giavazzi and Giovannini, 1986; Gandolfo and Padoan, 1988) and others taking a more optimistic view (De Grauwe, 1989). The EEC rules admit that, in particular circumstances, a country may temporarily reimpose exchange controls. These would share with the constraints applied in the past the characteristic of asymmetry, in that they would be applied to residents only.

An intuitive conclusion underlies the results obtained in this paper:[15] since asymmetric controls only constrain residents, their effectiveness depends on the importance of domestic agents in the world financial market. In a financial system which was, except for capital controls, internationally integrated, the weight of agents resident in a small economy would be irrelevant and the effectiveness of asymmetric exchange controls applied in that economy correspondingly reduced. In particular, a policy mix of fiscal expansion and monetary tightness does, so to speak, increase the importance of foreign lenders for the equilibrium of the domestic financial market. In fact, such a policy puts a substantial amount of domestic liabilities in the hands of foreign investors and thus increases the relevance of their reaction to exogenous shocks.

The practical, economic policy conclusion we derive from our analysis is that the effectiveness of the safeguard clause written in the EEC legislation in decoupling domestic interest rates from foreign ones and protecting official reserves in the face of external financial shocks is reduced, at the limit to nothing: i) as the country concerned follows a strict monetary policy and/or a lax fiscal policy and exchange controls aim at limiting outflows of capital; ii) as domestic and foreign assets tend to be perfect substitutes;[16] iii) as the country represents a small segment of an integrated (but for capital controls) financial system.

Any policy conclusion, however, should also take into account the real world factors which are not included in the models examined above.

Just to make an example, it is conceivable that, in a setting like the EMS, the expectation of an imminent devaluation could be crushed by the temporary imposition of exchange controls. This, in fact, could be interpreted by the market as a credible commitment from the authorities to avoid any realignment. One can also see that market imperfections and frictions, which do exist in practice, can increase the effect of controls. It is also easy to see, however, that investors would prefer foreign assets to domestic ones if, although yielding istantaneously the same return, there was an expectation that the return on domestic assets could be brought down, relative to foreign assets, by the imposition of exchange controls. This kind of expectation could be raised by the very existence of a safeguard clause. Thus, a country could pay with higher instantaneous interest rates the legal ability to, partially, insulate domestic interest rates in the face of eventual external shocks.

Many other factors can have a bearing on the assessment of the macroeconomic relevance of safeguard clauses allowing the temporary reimposition of exchange controls. Ultimately, the choice, as in many other instances, is a matter of informed and educated judgement. On balance, the contribution of this paper to this judgement is more in line with the arguments of those who see limited scope for exchange controls than with the arguments of those who fear dramatic macroeconomic consequences from the progressive liberalization of foreign exchanges.

Notes

(*) Discussions with and comments by W. Branson, S. Fischer, C. Goodhart, H. Hermann, C. Mann, M. Mentini, R. Raymond, R. Rinaldi and G. Vaciago helped to focus some of the ideas the paper contains. Part of it was written while Papadia was visiting the Department of Economics of MIT. The content of the paper, its drawbacks and mistakes are entirely the responsibility of the authors.

1. Micossi and Rossi (1986), p. 46.

2. Papadia and Vona (1988), p. 118.

3. And, in countries like Italy, the national legislation as well.

4. See Papadia and Vona (1988), para. 4. These authors also proved that, even in the case of a "temporary" or "minor" reversal of the policy mix, asymmetric capital controls remain not binding.

5. It remains true, however, that the model, as the original one by Dornbusch and all those which were derived from it, is not particularly well equipped to study steady-state properties, and the path leading to them.

6. This model derives, with substantial simplifications, from those developed by Allen and Kenen (1980), and Branson and Henderson (1985).

7. Thus, for instance, $B_1 = \partial B/\partial R$, while $b_1 = \partial(B/W)/\partial R$.

8. A tilde denotes a macroeconomic policy variable.

9. Overlooking capital gains is legitimate in this model, where bonds last one period and the exchange rate is fixed.

10. This could be done in a simple way by adding to the model a demand function for foreign bonds by foreigners:

$$F^* = W^* f^*(R,R^*),$$

and imposing the equilibrium condition on the foreign bond market:

$$\tilde{F}^* = F^* + MF + F.$$

Foreign wealth would remain exogenous, while we would have one more instrumental variable, i.e. the total supply of foreign bonds ($\tilde{F}^*$). In the model of the text, Notes

(10. cont'd)
instead, the latter is assumed perfectly elastic to the interest rates.

11. The dynamic stability of the model can be easily demonstrated noting, from (8), that: $\partial(dW/dt)/\partial W < 0$.

12. Notice that, since $\alpha = S_2/|S_3|$ and, from (2), $b = \partial B/\partial W = B_3$:

$$|B_2^*| + |B_2| - \alpha b > |B_2^*| \quad \Leftrightarrow$$

$$|B_2| - \frac{S_2}{|S_3|} B_3 > 0 \quad \Leftrightarrow$$

$$|S_3||B_2| > S_2 B_3.$$

The latter inequality is a necessary (and sufficient) condition for $dR|_n > 0$. It will be certainly satisfied assuming, in general, that saving is more reactive to changes in wealth than to changes in interest rates, and that the opposite holds for any asset demand (see Allen and Kenen, 1980).

13. Since $\alpha m < \mu$ (see footnote 12).

14. Since $\beta > \alpha b$ (see footnote 12).

15. The same conclusion was also drawn with a Mundell-Fleming model, in Papadia and Vona (1988).

16. Palmisani and Rossi (1987), using a framework similar to that of Para. 3 with perfect substitutability, showed further that <u>permanent</u> controls are always redundant as a means to protect reserves against fluctuations in foreign interest rates and/or exchange rate expectations. On the contrary, Grilli and Hamaui (1988) argued that truly effective exchange controls <u>must</u> be permanent.

APPENDIX

Let us consider a discrete-time, stochastic version of the Dornbusch (1976) model, with asymmetric capital controls:

$$\text{(A1)} \quad r_t = (r_t^* - \tau_t) + d_t,$$
$$\text{(A2)} \quad d_t = E_t\,(e_{t+1}) - e_t,$$
$$\text{(A3)} \quad m_t - p_t = -\alpha r_t, \qquad \alpha > 0,$$
$$\text{(A4)} \quad D_t = X_t + U_t,$$
$$\text{(A5)} \quad X_t = \chi(e_t - p_t), \qquad \chi > 0,$$
$$\text{(A6)} \quad p_t - p_{t-1} = \pi D_t, \qquad \pi > 0,$$
$$\text{(A7)} \quad K_t - K_{t-1} = X_t + R_t K_{t-1},$$

$$\text{(A8)} \quad \tau_t = \begin{cases} 0, & \text{if: } K_t < 0, \\ \tau > 0, & \text{if: } K_t \geq 0. \end{cases}$$

Small letters denote natural logarithms.

Eqq. (A1) and (A2) reflect perfect asset substitutability and perfect capital mobility, but for the imposition of capital controls: the domestic interest rate r_t must equal the foreign interest rate r_t^*, net of a tax τ_t on the income from residents' holdings of foreign assets (see below), plus the expected depreciation, d_t, of the exchange rate, e_t (defined in units of domestic currency). E_t is the expectation operator, conditional on all information through t.

According to (A3), the demand for nominal money balances m_t, deflated by the price of domestic output p_t, is a decreasing function of the interest rate. Income is excluded from this equation, and, for that matter, from the entire model, because it is assumed constant at full employment. Eq. (A4) states that excess demand for home goods D_t is equal to net exports X_t, plus a fiscal policy "shock" U_t. This formulation rules out any direct effect of the rate of interest on demand, since private domestic demand is equal to (constant) domestic output; further, it implies that net interest flows on the stock of foreign assets held by residents have no effect on domestic demand.

Net exports are assumed in (A5) to be a log-function of the relative price of home goods (the price of foreign goods is normalized at 1). Equation (A6) is a Phillips curve where the inflation rate is a function of excess demand. Eq. (A7) is the balance of payments identity when the exchange rate is perfectly flexible (and official reserves are constant), where K_t is the stock of foreign assets held by residents (if positive) or the stock of domestic assets held by non-residents (if negative); in both cases, K_t is measured in units of domestic currency and the domestic rate of interest (R_t, in natural terms) applies. The model only considers, for simplicity, the net foreign position and not gross assets and liabilities. Eq. (A8) is a way to model asymmetric exchange controls, stating that a tax is applied on residents' income from holdings of foreign assets but not on non-residents' income from holdings of domestic assets.

We are interested in finding under what configurations of monetary and fiscal policies asymmetric capital controls are binding, i.e. affect the solution to the model.

The model (A1)-(A8) can be rearranged in matrix form as follows:

(A9) $$E_t\,(z_{t+1}) = Az_t + Bm_t + CU_t + T(r_t^* - \tau_t),$$

where:

$$z_t = \begin{pmatrix} e_t \\ p_{t-1} \end{pmatrix},$$

$$A = \frac{1}{1+\beta} \begin{pmatrix} 1+\beta\left(1+\frac{1}{\alpha}\right) & \frac{1}{\alpha} \\ \beta & 1 \end{pmatrix}, \qquad \beta = \pi\chi > 0,$$

$$B = \begin{pmatrix} -\frac{1}{\alpha} \\ 0 \end{pmatrix},$$

$$C = \frac{\pi}{1+\beta} \begin{pmatrix} \frac{1}{\alpha} \\ 1 \end{pmatrix},$$

$$T = \begin{pmatrix} -1 \\ 0 \end{pmatrix}.$$

Let us investigate the effects of a monetary contraction. Following Taylor (1986), let us assume that:

$$\text{(A10)} \quad m_t = \sum_{i=0}^{\infty} \rho^{i-k} \mu_{t-i},$$

where μ_t is a serially uncorrelated random variable with zero mean. We can study the effects, ceteris paribus, of a permanent and unanticipated impulse given to the money supply, assuming that $\rho = 1$ and $k = 0$, and writing e_t and p_t as linear functions of current and past monetary perturbations, with unknown coefficients $\gamma_{e,i}$ and $\gamma_{p,i}$:

$$
\text{(A11)} \qquad
\begin{aligned}
e_t &= \sum_{i=0}^{\infty} \gamma_{e,i} \, \mu_{t-i} , \\
p_t &= \sum_{i=0}^{\infty} \gamma_{p,i} \, \mu_{t-i} .
\end{aligned}
$$

If we posit $\gamma_i = (\gamma_{e,i}, \gamma_{p,i-1})$, $i = 0, 1, \ldots$, where $\gamma_{p,-1} = 0$, substitution of (A11) into (A9) gives, assuming the fiscal policy and the foreign interest rate shocks in (A9) to be zero, and the monetary policy shock to be contractionary (negative):

$$
\text{(A12)} \qquad \gamma_{i+1} = A\gamma_i - B , \quad i = 0, 1, \ldots,
$$

which is a deterministic, non-homogeneous, first-order system of difference equations, whose unknowns represent the dynamic elasticities of the exchange rate and of the level of domestic prices to the supply of money.

A particular solution of (A12) is $\bar{\gamma}_i = (-1, -1)$, $i = 0, 1, \ldots$; this means that, in equilibrium, a monetary contraction causes the exchange rate to appreciate and the price level to decrease in the same proportion. To identify the path of the two variables to the new equilibrium values, we have to find the complete solution to (A12).

The characteristic roots of A are:

$$\text{(A13)} \quad \begin{matrix} \lambda_1 \\ \lambda_2 \end{matrix} = \frac{1}{2} + \frac{\alpha + \beta \pm \sqrt{\Delta}}{2\alpha\,(1 + \beta)} \quad , \quad \Delta = \beta^2\,(1+\alpha)^2 + 4\alpha\beta > 0$$

If one assumes that $\lambda_1 > 1$ and $0 < \lambda_2 < 1$, then the system has a unique stationary solution. The initial conditions coherent with this solution, i.e. the impact effects of the monetary shock, can be derived from:

$$\text{(A14)} \quad \begin{bmatrix} \gamma_{e,1} \\ \gamma_{p,0} \end{bmatrix} = A \begin{bmatrix} \gamma_{e,0} \\ 0 \end{bmatrix} - B \ ,$$

$$\gamma_{e,1} + 1 = - \frac{h_{1,p}}{h_{1,e}} \left(\gamma_{p,0} + 1\right) \ ,$$

where $(h_{1,e}, h_{1,p})$ is the characteristic vector of A corresponding to the unstable root λ_1. It is[1]:

$$\text{(A15)} \quad \frac{h_{1,p}}{h_{1,e}} = \frac{\sqrt{\Delta} - \beta(1+\alpha)}{2} > 0,$$

and:

1. Since $\Delta = \beta^2\,(1+\alpha)^2 + 4\alpha\beta > B^2\,(1+\alpha)^2$.

$$\text{(A16)}\quad \begin{aligned} \gamma_{e,0} &= -\frac{1+\theta}{1+\phi\theta} < -1, \\ \gamma_{p,0} &= -\frac{\phi+\phi\theta}{1+\phi\theta}, \quad -1 < \gamma_{p,0} < 0, \end{aligned}$$

where:

$$\theta = \frac{1}{\alpha} + \frac{h_{1,p}}{h_{1,e}} > 0,$$

$$\phi = \frac{\beta}{1+\beta}, \quad 0 < \phi < 1.$$

To derive the complete solution, describing how the system gradually adjusts to the shock, we first have to solve the homogeneous system:

$$\text{(A17)}\quad \begin{aligned} \gamma^{(H)}_{p,i+1} &= \lambda_2 \gamma^{(H)}_{p,i} \\ \gamma^{(H)}_{e,i} &= -\frac{h_{1,p}}{h_{1,e}} \gamma^{(H)}_{p,i-1} \end{aligned} \quad , \quad i = 1,\ 2,\ \ldots$$

and then add the particular solution (-1, -1). Overall, we get:

$$\text{(A18)}\quad \begin{cases} \gamma_{p,i} = K\lambda_2^{i} - 1 \\[2ex] \gamma_{e,i} = -\dfrac{h_{1,p}}{h_{1,e}} K\lambda_2^{i-1} - 1 \end{cases} \quad , \ i = 1, 2, \ldots$$

where K is an arbitrary constant. From (A14) can be derived:

$$\text{(A19)}\quad \gamma_{e,1} = -1 - \frac{h_{1,p}}{h_{1,e}} (1 + \gamma_{p,0}).$$

Equating the second equation in (A18) (for i = 1) and (A19), solving for K and substituting into (A18) we get:

$$\text{(A20)}\quad \begin{cases} \gamma_{p,i} = -1 + (1 + \gamma_{p,0})\lambda_2^{i} > -1 \\[2ex] \gamma_{e,i} = -1 - \dfrac{h_{1,p}}{h_{1,e}} \left(1+\gamma_{p,0}\right) \lambda_2^{i-1} < -1 \end{cases} \quad i = 1, 2, \ldots$$

Eq. (A20) shows that the effect of a monetary contraction is a deterioration of competitiveness, except in equilibrium, because the elasticity of the price level to a monetary, negative impulse is less than one, while that of the exchange rate is more than one. From eq. (A7), taking into account (A5) and (A16), we have:

(A21) $K_0 = X\,(\gamma_{e,0} - \gamma_{p,0}) < 0$

which shows that, on impact, the net foreign position is negative, as a consequence of monetary contraction, assuming that before the shock net exports and net foreign wealth were zero. Net foreign wealth of course remains negative for any subsequent period, since net exports are negative while converging to their long-run zero equilibrium, while interest payments on net foreign debt add to it. The asymmetric capital controls of eq. (A8) thus remain inactive.

For the analysis of a fiscal, expansionary shock assume that:

(A22) $$U_t = \sum_{i=0}^{\infty} \sigma^{i-k} \nu_{t-i} \,,$$

(A23) $$e_t = \sum_{i=0}^{\infty} \delta_{e,i} \nu_{t-i} \,,$$

(A24) $$p_t = \sum_{i=0}^{\infty} \delta_{p,i} \nu_{t-i} \,.$$

Substituting (A22) to (A24) into (A9), where the monetary policy and the foreign interest rate shocks are assumed to be nil, we get:

(A25) $\delta_{i+1} = A\delta_i + C \,, \quad i = 0, 1, \ldots$

where $\delta_i = (\delta_{e,i} \,, \delta_{p,i})$ are the dynamic effects on the exchange rate and the domestic price level of a permanent, unanticipated, positive, unit impulse to domestic demand, given by the fiscal authority. A particular solution to (A25), which gives the new equilibrium values of δ_i after the shock, is:

$$\text{(A26)}\quad \bar{\delta}_i = \left(-\frac{1}{X}, 0 \right), \quad i = 0, 1, \ldots$$

The impact effects of the shock can be derived from:

$$\begin{bmatrix} \delta_{e,1} \\ \delta_{p,0} \end{bmatrix} = A \begin{bmatrix} \delta_{e,0} \\ 0 \end{bmatrix} + C,$$

(A27)

$$\delta_{e,1} + \frac{1}{X} = - \frac{h_{1,p}}{h_{1,e}} \delta_{p,0} < 0$$

It is:

$$\text{(A28)}\quad \delta_0 = \left(-\frac{1}{X}, 0 \right).$$

which shows that the elasticity of the exchange rate to a fiscal expansion is negative (appreciation) while that of the price level is nil: we therefore have a deterioration of competitiveness which, in analogy with the result recorded for the monetary contraction, brings about an increasingly negative foreign net position and leaves foreign controls, as modelled in eq. (A8), inactive.

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