Sterilization of Capital Inflows and Balance of Payments Crises*

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Abstract

Large capital inflows and repeated balance of payments crises (BOPC) associated with their sudden reversal have characterized the emerging market economies during the 90's. Sterilized intervention has been the most common response to capital inflows. This paper links the sterilization efforts with BOPC in a general equilibrium model.

We study an economy facing a temporary decrease in the international interest rate, and show that an attempt to sterilize capital inflows leads the economy to a BOPC, while a pure Currency Board would avoid it. We argue that this experiment is relevant to understand the 1994 Mexican currency crisis.

Key words: Balance-of-payments crises; Sterilization of capital inflows; Mexican crisis

JEL classification: F31 ; F32

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1. Introduction

Two main economic events have been dominant in the emerging market economies during the 90's: the substantial increase in capital inflows compared to the 80's, and the repeated balance of payments crises (BOPC) associated with the sudden reversals of these flows.

Capital flows to Latin America, which averaged less than \$ 20 billion a year in the 80's (approximately \$ 11 billion during its second half), increased to \$ 70 billion a year during the 90's (IMF, 1999). In developing Asia capital flows increased from an average of \$14.9 billion a year in the 1985-89 period to \$ 40 billion a year from 1990 to 1994 (Calvo et al., 1994). The volatility of capital flows has also increased. Sudden swings in capital flows have been followed in most cases by sharp BOPC and deep economic contractions (Calvo, 1998).

These events have generated a substantial debate among academics and policymakers. An ever-growing strand of the literature deals with the causes of BOPC. A separate but not totally unrelated strand of literature deals with the causes and consequences of the surge in capital flows to developing economies in the 90's. It has centered on whether this increase has been a consequence of external or internal factors, and on the optimal monetary/fiscal/exchange rate policies to face it.

Calvo et al. (1993 and 1994) highlighted the importance of external factors in the renewal of capital flows to Latin America at the beginning of the 90's. Capital flows increased not only to countries undergoing structural reforms, but also to some extent to countries that did not perform substantial changes to their (unsound) economic fundamentals. While the relative impact of events in developed economies on flows to emerging countries seems to have diminished more recently (Montiel and Reinhart, 1997 and 1999), they continue to be highly relevant to the determination of their “timing and magnitude” (Montiel and Reinhart, 1997)[1], and sudden capital flow reversals due to contagion from other regional emerging markets have become more common.

Developing countries seem to face periods of increased confidence and capital inflows, which in part stem from events in the industrialized economies and/or in the investor's assessment of the regional risk, and whose sudden reversal is uncertain, regardless of the domestic economic policies pursued.

There is also an extensive debate concerning the optimal monetary/fiscal/exchange rate policies to face capital inflows. Capital inflows generate an expansion in the domestic absorption of tradable goods and nontradable goods and services, which result in a deterioration of the current account and the real exchange rate, respectively. These effects are widely considered as symptoms of economic fragility by academics and analysts, as they have been typically present in countries that suffered recent BOPC.

This has led policymakers to try to avoid the appreciation of the real exchange rate and the deterioration of the current account. The most widespread type of intervention has been the sterilization of capital inflows. Six out of eight Latin-American and Asian developing countries included in Montiel and Reinhart's (1997) study maintained extended sterilization policies. By placing (usually short-term) bonds in the domestic market, monetary authorities intend to avoid the expansion of domestic absorption and the other initial effects of capital inflows.

At least three objections can be placed to the sterilization of capital inflows:

1- By selling bonds in the domestic market the central bank prevents the domestic interest rate to converge to the international one (Reinhart and Reinhart, 1998), inducing more capital inflows and exacerbating the initial problem.

2- The low maturity of bonds typically used to sterilize increases the vulnerability of the economy (Montiel and Reinhart, 1997).

3- Higher domestic interest rates bring increased fiscal deficits.

This is the first paper to model in a general equilibrium framework the relationship between the sterilization of capital inflows and balance of payments crises.[2]

We exploit the fact that the sterilization of capital inflows increases the domestic interest rate and the fiscal deficit, and consider the case of an economy that faces a temporary decrease in the international interest rate. This pattern, originated in economic events in developed countries or in other countries in the region, seems to be the one that developing economies have faced in the 90's, as we argued above. We show that an attempt to sterilize capital inflows leads the economy to a BOPC. The mechanics are the following. The sterilization of *capital inflows* increases the domestic debt and the central bank's deficit in the period of low international interest rates. When international interest rates rise, the sterilization of *capital outflows* reduces the relative return of domestic bonds and increases the incentives for a speculative attack in that market, which leads the economy to a BOPC. Its empirical relevance depends, in turn, on the length of the sterilization effort and on the magnitude of the international interest rate decrease. The BOPC is avoided if the domestic interest rate is allowed to converge to the international one, as in a currency board.

Finally, in our model the BOPC takes place mainly through a speculative attack in the domestic bond market, a feature observed in some of the recent episodes.[3]

This case seems particularly relevant for the understanding of the 1994 Mexican currency crisis. Some of the previous papers that formalized the Mexican events (e.g., Kumhof, 1998) assume that the non-financial public sector deficit was the driver of the currency crisis when, in fact, it was very low in the years preceding the crisis. On the other hand, when international interest rates were low during 1992 and 1993 (see Figure 1), the Central Bank sterilized capital inflows with short-term bonds, and later did the opposite (sterilization of capital outflows) when the international interest rate started to rise in 1994, months before the crisis (see Figure 2).

[Figure 1 about here]

[Figure 2 about here]

The rest of the paper is organized as follows. In Section 2 the theoretical model is described. In Section 3 we show that an attempt to sterilize capital inflows stemming from a temporary decrease in the international interest rate puts the economy on a path leading to a BOPC, an event that would be avoided by a pure currency board. Section 4 concludes.

2. The Model

In this section we develop a simple perfect foresight model of a small open economy in which the demand of money and domestic bonds is motivated by a liquidity-in-advance constraint. It can be considered as an intermediate step between the models of Calvo and Vegh (1990), as we incorporate a more realistic exogenous fiscal constraint, and Kumhof (1998), as we exclude banks from the analysis.

There is one tradable good, whose supply is given as a constant endowment each period to the representative agent. The representative agent has also access to an interest-bearing international asset.

2.1 The Households

The economy is populated by an infinitely-lived representative household that maximizes the lifetime discounted utility from consumption *c*

$$U_t = \int_t^{\infty} u(c_s) e^{-\rho(s-t)} ds \tag{1}$$

where $u(c)$ is C^2, strictly concave, $u'(c) > 0$, and $u'(c) \rightarrow \infty$ as $c \rightarrow 0$.

Assume that the HH preferences are of the CEIS type[4]

$$u(c_t) = \frac{c_t^{1-\frac{1}{\delta}}}{1-\frac{1}{\delta}}$$

Households can invest in three types of assets:

i. domestic money, m_t

ii. domestic bonds issued by the government, d_t, which pay a nominal interest rate of i_t each period.

iii. international assets, b_t, which pay a (constant) interest rate of r_t each period (*r* is strictly positive).[5]

Assume for simplicity that $\rho = r$, to avoid introducing unnecessary dynamics in the model. The demand for the first two assets is motivated by a liquidity-in-advance (LIA) constraint

$$L(m_t, d_t) \geq \alpha c_t \tag{2}$$

where 0< α <1. We assume that L has a CES form

$$L = A(\omega m_t^{\frac{\sigma-1}{\sigma}} + (1-\omega)d_t^{\frac{\sigma-1}{\sigma}})^{\frac{\sigma}{\sigma-1}}$$

where $\sigma > 0$, $L_m > 0$, $L_d > 0$, $L_{md} > 0$, $L_{mm} < 0$, $L_{dd} < 0$ and L is homogeneous of degree one.

Let a_t be total household's wealth at time t. Then

$$a_t = m_t + d_t + b_t$$

PPP holds and without loss of generality we can assume that international inflation is zero so domestic inflation equals the devaluation rate (i.e., $\dot{p} = \varepsilon$). Then total wealth evolves according to

$$\dot{a} = y + g - c + ar - d(r + \varepsilon - i) - m(r + \varepsilon) \tag{3}$$

where y is the constant endowment per period and g are the net lump-sum transfers received from the government. This is a differential equation in a.[6] Note that for the LIA constraint to be binding, it must be the case that the opportunity costs of money and domestic bonds are strictly positive:

i. $r + \varepsilon > 0$. The opportunity cost of money balances has to be strictly positive. This is true even when $\varepsilon = 0$, as $r > 0$.

ii. $r + \varepsilon > i$. Foreign bonds must dominate local ones. This seems to contradict the fact that emerging markets' local bonds typically pay a premium over international interest rates, and it is a consequence of the way bonds are introduced in the model. The interest rate differential can be considered a liquidity premium, as domestic bonds in this economy provide necessary liquidity services.[7]

From equation (3) we can obtain the present value budget constraint

$$a_t + \int_t^{\infty} (y + g_s) e^{-r(s-t)} ds = \int_t^{\infty} (c_s + d_s (r + \varepsilon_s - i_s) + m_s (r + \varepsilon_s)) e^{-r(s-t)} ds \qquad (4)$$

Equation (4) expresses that at every point in time the initial wealth plus the present value of all future earnings (LHS) must equal the present value of future consumption plus the opportunity cost of holding money and domestic bonds (RHS).

The household's problem is to maximize equation (1) subject to equations (2) and (4), given the initial conditions, by optimally choosing *c* and asset demands. The conditions imposed imply the existence of an interior solution to this problem. We will assume that the LIA constraint is binding. Let λ be the multiplier of constraint (4) in the Hamiltonian. The FOC with respect to money holdings and domestic bond holdings are respectively

$$u'(c_t) = \lambda \left[1 + \frac{\alpha}{Lm_t} (r + \varepsilon_t) \right] \qquad (5)$$

and

$$u'(c_t) = \lambda \left[1 + \frac{\alpha}{Ld_t} (r + \varepsilon_t - i_t) \right] \qquad (6)$$

where Lm_t and Ld_t are the partial derivatives of L with respect to money and bond holdings respectively. From equations (5) and (6) we can deduce that

$$\frac{Ld_t}{Lm_t} = \frac{r + \varepsilon_t - i_t}{r + \varepsilon_t} \qquad (7)$$

which, along with the functional forms assumed for the LIA constraint, implies that the relative demand of money and domestic bonds depends only on their relative returns

$$\frac{m_t}{d_t} = \left(\frac{r + \varepsilon_t - i_t}{r + \varepsilon_t} \right)^{\sigma} \left(\frac{\omega}{1 - \omega} \right)^{\sigma} \qquad (8)$$

Define $I_t = r + \varepsilon_t$. Following Kumhof (1998), let $W \equiv \left(\frac{\omega}{1-\omega}\right)^{\sigma}$, $X_t \equiv \frac{I_t - i_t}{I_t}$ and

$\Phi(X_t) \equiv X_t^{\sigma}$. Then we can express $\frac{m_t}{d_t} = W\Phi(X_t)$

where: $\left.\frac{\partial \frac{m_t}{d_t}}{\partial r_t}\right|_{i,\varepsilon} = \left.\frac{\partial \frac{m_t}{d_t}}{\partial \varepsilon_t}\right|_{i,r} > 0$ and $\left.\frac{\partial \frac{m_t}{d_t}}{\partial i_t}\right|_{\varepsilon,r} < 0$

given that $\left.\frac{\partial X_t}{\partial r_t}\right|_{i,\varepsilon} = \left.\frac{\partial X_t}{\partial \varepsilon_t}\right|_{i,r} > 0$ and $\left.\frac{\partial X_t}{\partial i_t}\right|_{\varepsilon,r} < 0$

Using the assumption that the LIA constraint is binding and the fact that it is homogeneous of degree one, we can derive demand equations for both domestic assets

$$d_t = \frac{\alpha c_t}{L(W\Phi(X_t),1)} \tag{9}$$

and,

$$m_t = \frac{\alpha c_t W\Phi(X_t)}{L(W\Phi(X_t),1)} \tag{10}$$

In order to facilitate the exposition of the following sections, it is important to understand the effects on money and bond demands of changes in their relative return and the consumption level. As $\frac{m_t}{d_t}$ depends only on W and $\Phi(X_t)$, then it is easy to see that

$$\left.\frac{\partial m_t}{\partial c_t}\right|_{i,\varepsilon,r}, \left.\frac{\partial d_t}{\partial c_t}\right|_{i,\varepsilon,r} > 0$$

We call these changes **level effects**. By Euler's Theorem, it also follows that

$$\left.\frac{\partial m_t}{\partial X_t}\right|_c > 0 \text{ and } \left.\frac{\partial d_t}{\partial X_t}\right|_c < 0$$

so that money balances actually *increase* when inflation or the international interest rate increase and decrease when the interest rate paid on domestic bonds increases. The opposite is true with respect to domestic bonds. We call these changes **substitution effects**.[8]

Define (total domestic) liquid assets as

$$l_t \equiv m_t + d_t \tag{11}$$

Then (see Appendix 1 for a proof)

$$\left.\frac{\partial l_t}{\partial c_t}\right|_{r,i,\varepsilon} > 0 \text{ and } \left.\frac{\partial l_t}{\partial X_t}\right|_c < 0$$

So when inflation or the international interest rate go up liquid assets demand decreases, as the fall in the demand of domestic bonds exceeds the increase in money demand. This is because in equilibrium the marginal productivity of government debt is lower than that of money in providing liquidity services (see equation (7)) and so money, being more productive at the margin, varies less than government debt.

2.2 The Government

We assume that the government fixes the interest rate on domestic bonds at $\bar{i}$, so that $i_t = \bar{i}\ \forall t$. At each point in time, the consolidated public sector budget constraint is

$$g_t + \bar{i} d_t + \dot{k}_t = r_t k_t + \varepsilon_t (m_t + d_t) + \dot{d}_t + \dot{m}_t \tag{12}$$

at points of continuity and

$$\Delta k_t = \Delta m_t + \Delta d_t$$

at jump points, where k_t are the international reserves held by the central bank. Equation (12) has the interpretation that at each period net government lump-sum transfers plus interest expenses and asset's changes (LHS) have to equal government revenues plus liabilities change (RHS). Moreover, at some points in time there can be discrete swaps of domestic money or bonds for international reserves.

We also assume that the central bank fixes the exchange rate (i.e., $\varepsilon = 0$), and that there is a lower bound on the central bank's international reserves, below which it will abandon the peg. Assume for simplicity that this bound is zero (i.e., $k_t \geq 0 \;\; \forall t$).

Throughout this paper we assume that the government follows an exogenous fiscal policy, setting a path for g_t in advance. If an overall deficit results, it has to be financed either by new debt, or by monetary expansion, or by the devaluation tax $(\varepsilon_t(m_t + d_t) > 0)$. If the demand of money and domestic bonds is constant in real terms, and if $\varepsilon = 0$, then any money-financed deficit will result in reserve losses.

We also assume the government initially runs consistent monetary, fiscal and exchange rate policies. From equations (5), (9) and (10) we can see that for ε, r and i fixed, consumption and the demand of money and domestic bonds will be constant (implying that). From equation (12) we can see that $\dot{k}_t = 0$ if and only if

$$rk_t = g_t + \bar{i}\, d_t \tag{13}$$

so the government needs a primary surplus ($g < 0$) sufficient to cover net interest payments in order to achieve global fiscal balance.[9]

2.3 The Aggregate Economy

Total net foreign bond holdings in the economy, f_t, are the addition of HH's holdings and Central Bank's reserves

$$f_t = b_t + k_t \tag{14}$$

So $\dot{f}_t = \dot{b}_t + \dot{k}_t$, and the evolution of total foreign bond holdings in the economy is equal to

$$\dot{f}_t = rf_t + y - c_t \tag{15}$$

which means that the accumulation of net foreign assets is equal to the current account balance. Integrating forward and imposing the transversality condition $\lim_{t\to\infty} f_t e^{-rt} = 0$, we get the economy's lifetime resource constraint

$$f_t + \frac{y}{r} = \int_t^{\infty} c_s e^{-r(s-t)} ds \tag{16}$$

implying that the present value of consumption (RHS) has to be equal to the present value of resources (LHS). Note that from equation we can also calculate the constant level of consumption that keeps the net foreign assets holdings unchanged from that period on

$$c_t = rf_t + y \tag{17}$$

2.4 Level Effects

Changes in r, ε, or i bring level effects only if they result in changes in the current consumption level. Current consumption levels can change either because of wealth effects or because of intertemporal substitution effects (IS).

The term between brackets at the RHS of equation is the *effective price of consumption*, $q_{t,}$ which increases when I_t increases (i.e.: when r or ε increase), and decreases when i_t increases.

To be more explicit, we follow Calvo and Vegh (1990) and assume for now that $\delta = 1$ (i.e.: that the utility function is logarithmic). Then we can express consumption as

$$c_t = (rf_0 + y)\frac{\dfrac{1}{r\displaystyle\int_0^\infty \dfrac{e^{-rt}dt}{\left[1 + \dfrac{\alpha}{Ld_t}(r + \varepsilon_t - i_t)\right]}}}{\left[1 + \dfrac{\alpha}{Ld_t}(r + \varepsilon_t - i_t)\right]} \qquad (18)$$

where Calvo and Vegh call the last term on the RHS the Marginal Propensity to Consume (MPC) out of permanent income. We can think of it as the ratio of the average effective price of consumption to the current one.

Unanticipated fluctuations in r (temporary or permanent) bring wealth effects, as they modify the lifetime resource constraint of the economy (equation). For the same reason, changes in i or ε (temporary or permanent) do not bring wealth effects.

A temporary change in i or ε brings an intertemporal substitution effect, as it modifies the effective price of consumption unevenly across time (i.e., change the MPC in equation (18)). With an exogenous fiscal constraint, permanent changes in i might be able to bring an intertemporal substitution effect, a result that differs from Calvo and Vegh (1990).

Finally, lets specify a result that will be used later.

Proposition 1. *An increase (decrease) in r and i in the same proportion increases (decreases) the effective price of consumption.*

Proof. Starting from q_t defined as in the RHS of equation, note that

$$\left.\frac{\partial q_t}{\partial I_t}\right|_i + \left.\frac{\partial q_t}{\partial i_t}\right|_I > 0$$

$$\Leftrightarrow \frac{\alpha}{Ld} + (I_t - i_t)\alpha \left.\frac{\partial\left(\frac{1}{Ld}\right)}{\partial I_t}\right|_i > \frac{\alpha}{Ld} - (I_t - i_t)\alpha \left.\frac{\partial\left(\frac{1}{Ld}\right)}{\partial i_t}\right|_I$$

$$\Leftrightarrow \left.\frac{\partial\left(\frac{1}{Ld}\right)}{\partial I_t}\right|_i > -\left.\frac{\partial\left(\frac{1}{Ld}\right)}{\partial i_t}\right|_I$$

$$\Leftrightarrow -\frac{i_t}{I_t} > -1$$

$$\Leftrightarrow i_t < I_t$$

which was assumed in order to have the LIA constraint holding in equality ■

3. Changes in International Interest Rates and BOPC

In this section we consider the case of a small open economy that faces an unexpected temporary decrease in the international interest rate at *t*=0. We assume that prior to that date the economy was in steady state. The path of international interest rates is given by[10]

$$r_t = r^l (= r_1) \qquad (0 \le t \le T)$$

$$r_t = r^h (= r_0) \qquad (t < 0 \text{ and } t \ge T)$$

where r^h and r^l ($r^h > r^l$) denote the high and low international interest rates, respectively (see Figure 3)

[Figure 3 about here]

We have already emphasized that such a pattern of capital inflows and sudden outflows following economic changes in developed countries seems to be the most relevant for emerging economies. In particular, this experiment seems to be relevant for the analysis of the 1994 Mexican currency crisis, as we argued in Section 1.

The temporary decrease in the international interest rate is expected to result in a surge of capital inflows, as the relative return of domestic assets increases. The central bank in our model can either reduce the domestic interest rate or keep it constant. We call **sterilization** to the case in which it keeps it constant, in analogy with the observation that the domestic interest rate increases (or does not fall) when central banks try to place the bonds with which they sterilize capital inflows. Figure 4 shows the time-path of the interest rate on the domestic bond in the sterilization case. We show that if the government tries to sterilize capital inflows, it sets the economy in a path leading to a BOPC.

[Figure 4 about here]

If, on the contrary, the government lets the domestic interest decrease along with the international one, no BOPC would take place. We call this case a **currency board arrangement** for two reasons. First, the empirical literature shows that domestic interest rates converged faster to the international one in countries with currency board arrangements at the beginning of the 90´s.[11] Second, absent risk, the relative returns of domestic and international bonds should stay the same if the government does not engage in an interest rate policy.[12] Figures 5 shows the time-path of the domestic bond interest rate in the case of the pure currency board.

[Figure 5 about here]

It would be more realistic to assume that the timing of the international interest rate reversal is uncertain. We derive our results assuming full certainty about T and leave the uncertain case for further research.

3.1 Pure Currency Board Case

In the pure currency board case, we can derive a general result.[13]

Proposition 2. *In the Currency Board case, an unexpected temporary decrease in the international interest rate does not set the economy in a path leading to a BOPC.*

Proof. We want to show that international reserves do not fall during the low international interest rate period, and so there will not be a currency crisis afterwards.

Define x as the percentage decrease in the international interest rate (i.e., $r_1 = r_0$ (1-x)). In this case the interest rate paid on domestic bonds experiences the same change as the international interest rate. This implies that the RHS of equation (8) remains unchanged, as

$$\frac{r_0(1-x)-i_0(1-x)}{r_0(1-x)}=\frac{r_0-i_0}{r_0}$$

meaning that there are no substitution effects at t=0. Assume for now that there are no level effects at t=0 also. Then budget balance requires

$$g_0+\bar{i}_0 d_0=r_0 k_0 \qquad \text{(for t<0)}$$

$$g_0+\bar{i}_0(1-x)d_0+\dot{k}_t=r_0(1-x)k_0 \qquad \text{(for t≥0)}$$

$$\dot{k}_t=-x(r_0 k_0-\bar{i}_0 d_0)$$

Given the conditions assumed $(r_0 k_0-\bar{i}_0 d_0=g_0<0)$, $\dot{k}_t>0$. This means that the central bank increases its international reserves during the period of low international interest rates. Now we want to argue that there is a positive level effect at t=0.

We have shown in Section 2 that a proportional decrease in r and i induces a decrease in the effective price of consumption. Let q^l and q^h be the effective price of consumption when the international interest rate is low and high, respectively. From t=0 to t=T the discount rate will be higher than the international interest rate and so consumption will not be constant throughout that period. In particular, as the representative agent is relatively impatient, he will have a decreasing consumption pattern. It can be shown that consumption in this case is given by

$$c_t=\Gamma*\Xi*(q^l)^{-\delta}e^{-(r_0-r_1)\delta t} \tag{19}$$

For 0≤ t≤ T, where

$$\Gamma=f_0+y\left(\frac{1-e^{-r_1 T}}{r_1}+\frac{e^{-r_0 T}}{r_0}\right)$$

and

$$\Xi = \frac{1}{(q^l)^{-\delta}\left(\frac{1-e^{-(r_1(1-\delta)+\delta r_0)T}}{r_1(1-\delta)+\delta r_0}\right)+(q^h)^{-\delta}\left(\frac{e^{-(r_0(1+\delta)-\delta r_1)T}}{r_0}\right)}$$

After $t=T$, consumption is equal to

$$c_t = c_T\left(\frac{q^l}{q^h}\right)^{\delta} \tag{20}$$

where C_T is given by equation (19) evaluated at $t=T$. From equations (19) and (20) we can deduce that:

- The MPC increases at $t=0$, as the denominator decreases more than the numerator (IS effect). In addition, as f_0 is assumed to be negative, a fall in the international interest rate increases the wealth of the representative agent (wealth effect). So at time $t=0$ there will be an increase in consumption.
- Consumption falls from $t=0$ to $t=T$. This can easily be seen by evaluating equation (19) at those points.
- Consumption falls at $t=T$, as $q^l < q^h$
- Consumption is constant after $t=T$

From the first of these points we see that there is a positive level effect at t=0. The positive level effect increases m, d, and hence to a greater extent k. This enhances the rate of growth of reserves, although this effect is partially offset by the fall in consumption up to t=T. ■

3.2 Sterilization

We model the **sterilization case** as that in which the Central Bank does not allow the domestic interest rate to be reduced along with the international one, raising the relative return of the domestic bonds and thus their demand.

This action deteriorates the position of the domestic public sector, which now receives less interest revenues from its international reserves and pays more for its domestic public debt (because quantities increase).[14] The impact of these changes on the finances of the public sector depends on the length of the international interest rate decrease, and the magnitude of the international interest rate decrease. For a very small decrease and/or a very short period of low interest rates, the sterilization effects can be insignificant from a practical point of view.

If the deterioration of the public sector finances brings a BOPC there are three possible cases, depending on whether it takes place before, during, or after the time at which the international interest rate rises again (*t*=*T*). We treat here only the last case. Figure 6 shows one possible path for international reserves.

[Figure 6 about here]

Note that we can distinguish four periods: [15]

1- Period 0 ($t \leq 0$)

The government runs consistent monetary, fiscal, and exchange rate policies. The international interest rate is r^h.

2- Period 1 ($0 < t \leq T$)

The international interest rate decreases to r^l, but the domestic interest rate is kept constant (i.e., $i > r^l$)

3- Period 2 ($T < t \leq T'$)

The international interest rate is back at r^h.

4- Period 3 ($t \geq T'$)

At *T*' there is a currency crisis and the government abandons the peg.

In the sterilization case we can derive the following result:

Result: *If the government tries to sterilize capital inflows when there is a temporary decrease in international interest rates, it sets the economy in a path leading to a BOPC.*

We have to show that this policy leads the economy to a collapse of the exchange rate at *t*=*T'*. This is done next in two steps. First we show that if this policy results in a loss of reserves that makes them hit their lower bound, then the devaluation rate (ε_3) will be strictly positive after *t*=*T'*. Then we show that this policy is in fact unsustainable (i.e., leads to a loss of reserves).[16]

First we have to show that if *k*=0 after *t*=*T*', $\varepsilon_3 > 0$. Budget balance after *t*=*T'* requires in this case that:

$$(\Psi \equiv)\varepsilon_3(m_3 + d_3) - g_0 - i_0 d_3 = 0 \tag{21}$$

Note that dividing both sides by d_3 we get, for *r* and *i* constant, a function of ε and *c*. As for positiveness, note that

$$\Psi(0,c) = -g_0 - i_0 d_3 < 0$$

by assumption, while (as $-g_0 > 0$)

$$\Psi(\varepsilon_3 = i_0, c) = i_0(m_3 + d_3) - g_0 - i_0 d_3$$

$$= i_0 m_3 - g_0 > 0$$

To prove monotonicity, divide both sides of equation (21) by d_3, to get

$$\varepsilon_3\left(\frac{m_3}{d_3}+1\right)-g_0\left(\frac{1}{d_3}\right)-i_0=0$$

Define: $\Theta=\frac{m_3}{d_3}$ and $\Upsilon=\frac{1}{d_3}$. We know that: $\left.\frac{\partial\Theta}{\partial\varepsilon_t}\right|_{r,i}>0$ and $\left.\frac{\partial\Upsilon}{\partial\varepsilon_t}\right|_{r,i}>0$ (see equation (8)). Then $g_0<0$ implies that a unique (positive) ε_3 satisfies condition (21).

Then we have to show that this policy leads to a depletion of reserves. The intuition is the following. The fall in international interest rates brings a substitution effect and a level effect at t=0. If there is a BOPC at some point in the future, there would be an additional level effect at t=0. The additional level effect would unambiguously increase the stock of domestic bonds at t=0. If it made the situation sustainable, then $\varepsilon_3 = 0$ and there would be no BOPC. But this is a contradiction, since the additional level effect is conditional on the BOPC taking place.

So we only need to show that the initial substitution and level effects leave the public sector unbalanced. Budget balance requires

$$g_0+\bar{i}_0 d_0=r_0 k_0 \qquad \text{(for t<0)}$$

$$g_0+\bar{i}_0(d_0+\Delta d_0)+\dot{k}_t=r_0(1-x)(k_0+\Delta k_0) \qquad \text{(for t≥0)}$$

$$g_0+\bar{i}_0 d_0+\bar{i}_0\Delta d_0+\dot{k}_t=r_0 k_0+r_0\Delta k_0-r_0 x(k_0+\Delta k_0)$$

$$\dot{k}_t=r_0\Delta k_0(1-x)-r_0 x k_0-\bar{i}_0\Delta d_0$$

So $\dot{k}_t<0$ from $t=0$ to $t=T$ iff

$$r_0\Delta k_0(1-x)-r_0 x k_0-\bar{i}_0\Delta d_0<0$$

$$\Leftrightarrow \quad x > \frac{(r_0 \Delta k_0 - \bar{i}_0 \Delta d_0)}{r_0 (\Delta k_0 + k_0)} \tag{22}$$

To calculate the values of Δk_0, Δd_0, and the level of reserves at $t=T$, we need the value of consumption throughout this period. From $t=0$ to $t=T$ the discount rate is higher than the international interest rate, and so the representative household will have a decreasing consumption path. We can calculate that

$$k_T = [k_0 + \Delta k_0] e^{r_1 T} - g_0 \left[\frac{r^{r_1 T} - 1}{r_1} \right] - F e^{r_1 T} \int_0^T c_t e^{-r_1 t} dt \tag{23}$$

where c_t is given by equation (19), and

$$F = \frac{i_0 \alpha}{A \left(\omega \left(\frac{r_1 - i}{r_1} \right)^{\frac{\sigma}{\sigma - 1}} + (1 - \omega)^{\frac{\sigma}{\sigma - 1}} \right)}$$

Note that we can simplify calculations by finding the constant consumption path that is equivalent (in present value) to the tilted one during the transition period. We want to find a constant c_1^* such that

$$\int_0^T c_1^* e^{-r_1 t} dt = \int_0^T c_t e^{-r_1 t} dt$$

It can be shown that c_1^* is given by

$$c_1^* = \Gamma * \Xi * \Lambda * (q^l)^{-\delta} \tag{24}$$

where Γ and Θ are as before, and

$$\Lambda = \left(\frac{1 - e^{-(r_1(1-\delta) + \delta r_0)T}}{r_1 (1 - \delta) + \delta r_0} \right) \left(\frac{r_1}{1 - e^{-r_1 T}} \right)$$

After $t=T$, public sector balance requires

$$g_0 + \bar{i}_0 (d_T - \Delta d_T) + \dot{k}_t = r_0 (k_T - \Delta k_T)$$

So $\dot{k}_t < 0$ for $t > T$ iff

$$r_0(k_T - \Delta k_T) - g_0 - \bar{i}_0(d_T - \Delta d_T) < 0 \tag{25}$$

where k_T is given by equation (23). We cannot derive analytically explicit thresholds (combinations of T and x in this case) above which the economy will have a BOPC at some (finite) point in the future. That is, we cannot check analytically whether conditions (22) and (25) are simultaneously satisfied and so reserves fall not only from t=0 to t=T, but also after t=T.

Numerical simulations show that any combination of x and T would lead the economy to a BOPC if the government tries to sterilize (details available upon request). What varies is the empirical relevance of these changes, as a small x and T would disrupt public finances by little and the BOPC would only be a distant event.

To gain further insight we ask the following question: what adjustment to the primary surplus would be needed at t=T to restore fiscal balance without losing reserves from then on (avoiding a future BOPC).

In Figure 7 we present the results of numerical simulations for different combinations of x and T in the case in which the discount case moves along with the international interest rate (not presented above), and in Figure 8 in the constant discount rate case. Values in the y-axis represent the fiscal adjustment as percent of GDP needed to restore fiscal balance at t=T. If there is, for example, a decrease in the international interest rate of 30 percent that lasts for T=9 periods, then at t=T the government has to increase the primary surplus in 0.3 percent of GDP to restore fiscal balance. Otherwise, a BOPC will take place in the future. As expected, longer periods of sterilization (i.e., of low international interest rates) and sharper reductions in the international interest rate (i.e., larger increases in the relative return of domestic bonds) lead to higher required fiscal adjustments at time *T*.

[Figure 7 about here]

It may seem that long years of low international interest rates are required to generate a sizable fiscal disequilibrium when the central bank sterilizes capital inflows. But that is not the case in the context of the model, as for reasonable parameter values it would take many periods to produce a first generation BOPC (results are available upon request).

In the examples just studied the sterilization of capital inflows unbalances the finances of the public sector. Monetization of the deficit leads to a loss of international reserves and ultimately to a BOPC, as shown in Figure 6. But this story contradicts the fact that countries that sterilize usually increase their international reserves during periods of low international interest rates (see Figure 2 for an example). This counterfactual result could be overcome if instead of assuming that the deficit is monetized we assume that it is financed with debt, and that there is an upper bound on the level of debt tolerated. We leave that exercise for further research.[17]

3.3. Discussion

We have argued in this section that an attempt by the central bank to sterilize the capital inflows that would follow from a temporary reduction in the international interest rate sets the economy in a path leading to a BOPC.

It is important to notice that in our model the government sterilizes twice. It first sterilizes capital inflows by not letting the domestic interest rate to decrease along with the international one. But it also sterilizes capital outflows after the international interest rate increases again, by keeping the domestic interest rate constant.[18]

The mechanics are the following. The sterilization of capital inflows increases the domestic debt in the period of low international interest rates, and the fiscal deficit created in this way reduces international reserves. When international interest rates rise, the sterilization of capital outflows reduces the relative return of domestic bonds and increases the incentives for a speculative attack in that market, which leads the economy to a BOPC.

It has been argued that this experiment is biased, in the sense that it only considers the case of a *temporary decrease* in the international interest rate for an economy that was at *steady state at the high international interest rate level*. But this seems to be the relevant setup to analyze the 1994 Mexican BOPC. The economy seemed not to be heading to a BOPC before 1992, and the Central Bank sterilized capital inflows from 1992 to February of 1994, when it started to sterilize capital outflows. The reason why we call 1992-93 a period of temporary low international interest rates is clear from Figure 1.

4. Conclusions and Further Research

Two main economic events have been dominant in the emerging market economies during the 90's: the substantial increase in capital inflows compared to the 80's, and the repeated balance of payments crises (BOPC) associated with the sudden reversals of these flows.

Empirical findings point out that external factors continue to be highly relevant to the determination of the ``timing and magnitude'' of capital flows to developing countries.

Policymakers have usually tried to avoid the expansionary effects of capital inflows, and sterilization has been the most widespread type of intervention.

This is the first paper to model in a general equilibrium framework the relationship between the sterilization of capital inflows and balance of payments crises. Many objections can be placed on sterilization, amongst them that it deteriorates the finances of the public sector. We have exploited this fact to argue that, under different assumptions concerning the consistency of the monetary/fiscal policy with the exchange rate peg, sterilization is never the best policy response to capital inflows. This is because the sterilization either anticipates the BOPC or puts the economy in a path leading to a BOPC while the currency board would not, depending on the assumptions. We have also shown that in the context of perfect foresight and perfect capital mobility sterilization is ineffective in the sense that it does not reduce the current account deficit.

Our results suggest that an attempt to sterilize the capital inflows that would follow from a temporary reduction in the international interest rate sets the economy in a path leading to a BOPC. We have analyzed the empirical relevance of this problem, which depends on the time-extension and the magnitude of the interest rate decrease. This case seems particularly relevant for the understanding of the 1994 Mexican currency crisis. Some of the previous papers that formalized the Mexican events assume that the non-financial public sector deficit was the driver of the currency crisis when, in fact, it was very low in the years preceding the crisis. On the other hand, when international interest rates were low during 1992 and 1993, the Central Bank sterilized capital inflows with short-term bonds, and later sterilized capital outflows when the international interest rate started to rise in 1994, months before the crisis.

Further research may extend the analysis in at least two directions. One is to lift up the assumption that deficits are monetized during the low international interest rates period. As argued above, this leads the model to have some conterfactual results. The second is to introduce uncertainty in the timing of the international interest rate hike. As Drazen and Helpman (1987) show in a different context, this may give additional interesting dynamics to the model.

Appendix 1

We want to show that

$$\left.\frac{\partial l_t}{\partial X_t}\right|_c < 0$$

$$\left.\frac{\partial l_t}{\partial X_t}\right|_c = \frac{\alpha C_t}{L^2}\left\{\Phi'(X_t)WL - (1+\Phi(X_t)W)\frac{\partial L}{\partial \Phi(X_t)}\Phi'(X_t)\right\}$$

$$= \frac{\alpha C_t}{L^2}\Phi'(X_t)W\left\{L - L_m - L_m\Phi(X_t)\right\}$$

The term in brackets is negative from Euler's Theorem and the fact that $L_m > L_d$ in equilibrium.

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[1] We have updated Calvo et al.'s (1993) methodology and analyzed the determinants of capital flows to nine emerging markets from 1990 to 1998, using quarterly capital flows data from the IFS. The countries included are Argentina, Brazil, Chile, Mexico, Peru, Indonesia, Korea, Philippines and Thailand. Our results indicate that there is a high degree of comovement in capital inflows among countries in the same region, and that they are highly correlated with a variable that reflects the liquidity conditions in developed countries. The results are available from the author upon request. Ades et al. (2000) find similar results for portfolio flows.

[2] Calvo (1996) presents a political-economy model showing that the sterilization of capital inflows leads to higher inflation and distortionary taxes than under no sterilization.

[4] In the standard Krugman-type model, at the time of the speculative attack there is a discrete fall in the monetary base. In some recent episodes, however, the speculative run has been centered in the domestic bonds' market, while the monetary base remained constant. Kumhof (1998) models this as the result of the efforts of the Central Bank to sterilize capital outflows at the time of the attack.

[10] We adopt Kumhof's functional forms.

[11] All the variables in the model are defined in domestic currency real terms, except for i .

[12] In what follows, we call γ primary balance. Note that $\gamma< 0$ denotes a primary surplus.

[13] This implies that Uncovered Interest Parity does not hold. If we could borrow in domestic currency at rate ι and invest in a foreign bond, we could get a per-period excess return of $r + \varepsilon - \iota$. But note that we cannot borrow at rate ι, since lending at that rate is dominated by lending at the "pure" (and certain) interest rate $r + \varepsilon$.

[14] Behind this apparently counter-intuitive result lies the fact that when the devaluation rate or the international interest rate increase, the opportunity cost of domestic bonds increases proportionately more than the opportunity cost of money balances. And, for a given level of consumption, the total liquidity services to provide remains the same.

[15] We assume that initially $id_t > rk_t$.

[18] Note that there is no risk in our model, but the changes in r could be well interpreted as changes in the risk associated with the region (due to, for example, contagion). Note also that the described path is a simplification, as in reality there is substantial evidence of interest rate smoothing. See Sack (1998).

[16] In reality, domestic interest rates in emerging markets are much higher than the US interest rate. The model, on the contrary, presents the anomaly of having the domestic interest rate lower than the international one. In reality, when the latter decreases, domestic rates decrease much faster in countries with currency board arrangements. By analogy, we assume the same in the model. More on this below.

[17] The analogy has its caveats. In a pure currency board the central bank only exchanges domestic money for international reserves, while in the model the central bank still accepts bond exchanges if it is asked to. We thank Martin Uribe for making us to note this. We show that as there is no substitution effect in a pure currency board, bond exchanges arise only as a consequence of level effects, and they are not significant.

[19] Kumhof (1999) proposes the reduction of domestic interest rates as an effective way to sterilize capital inflows. Here we go one step beyond, arguing that failing to lower the domestic interest rate could not only strengthen capital inflows, but also put the economy in a path leading to a BOPC.

[20] This is partially offset because the rise in the demand of domestic bonds at t=0 increases international reserves. But, for the same reason, money demand falls. Although the total substitution effect on liquid assets demand is positive (see Appendix 1), the increase in international reserves is lower than the one in domestic bonds outstanding.

[15] We use subscripts 0, 1, 2 and 3 for the variables in the corresponding periods.

[16] Here we do not calculate the timing of the speculative attack, as is usual in BOPC models (see Calvo, 1987, and Kumhof, 1998).

[22] See Drazen and Helpman (1990) for a similar exercise in another context.

[23] The sterilization of capital outflows is behind the results derived by Kumhof (1998). Lahiri and Vegh (1999), on the contrary, study the effects of fighting capital outflows with increased domestic interest rates.

Figure 1. US Short-Term Interest Rate

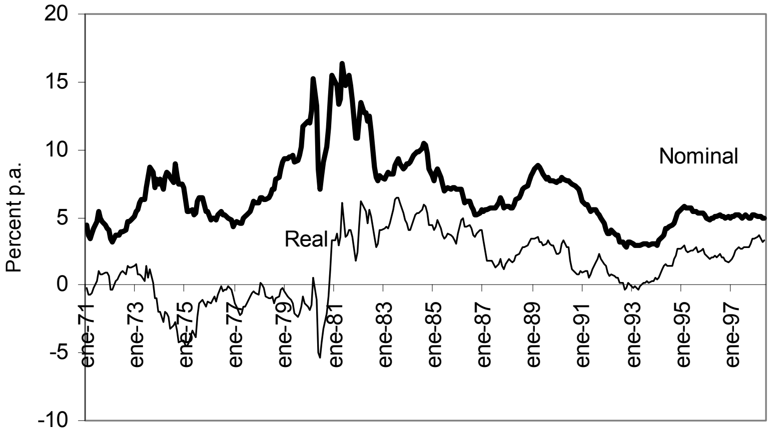

Figure 2. Mexico: Monetary Base and International Reserves

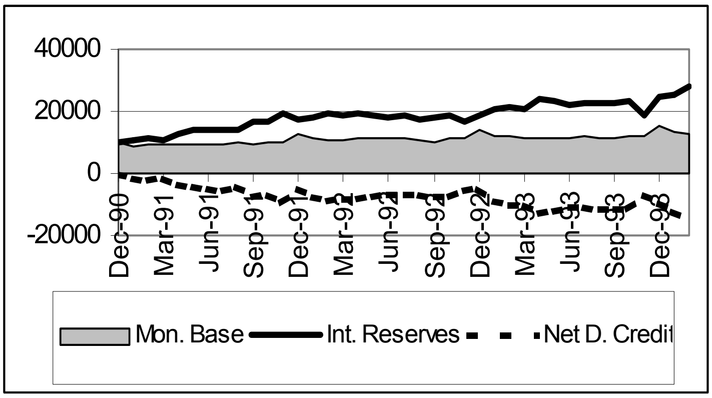

Figure 3. International Interest Rates

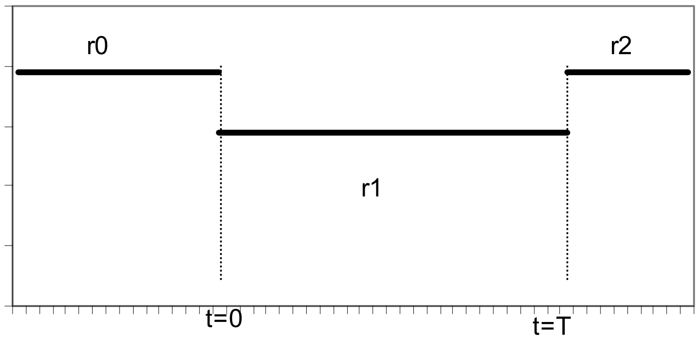

Figure 4. Sterilization case

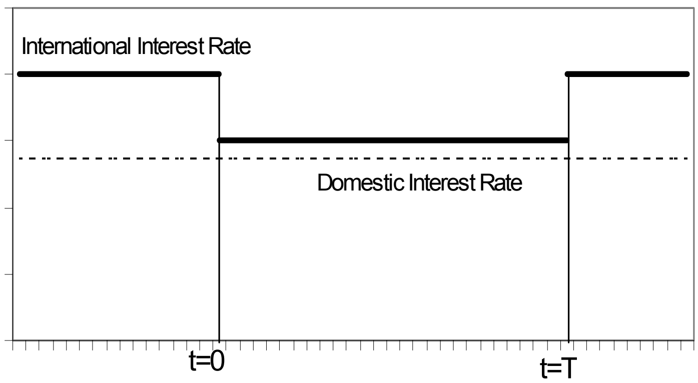

Figure 5. Currency board case

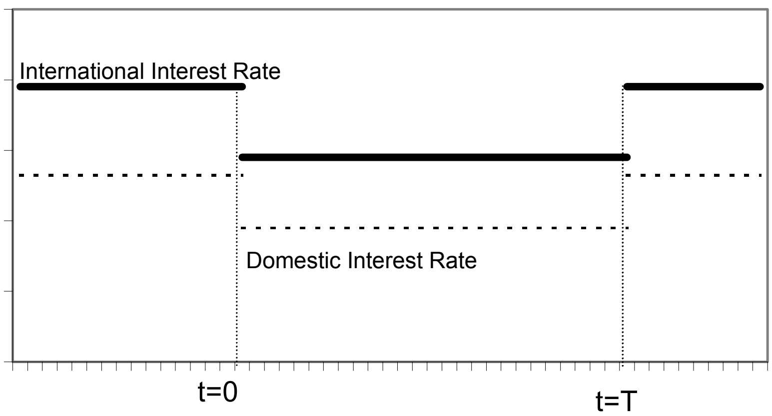

Figure 6. Evolution of International Reserves

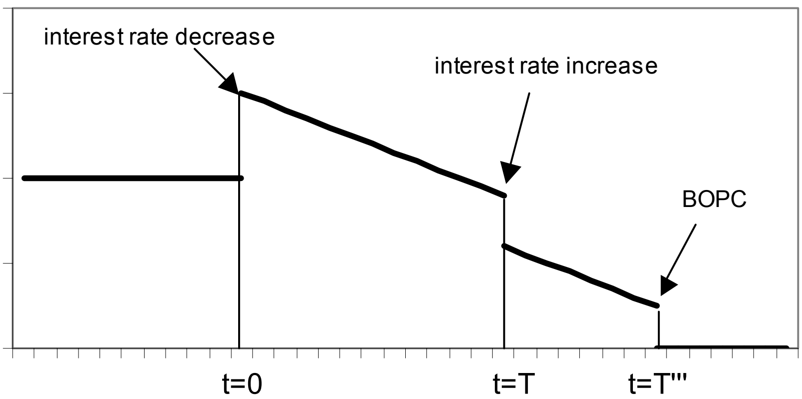

Figure 7. Fiscal adjustment at t=T (as % of GDP) needed to restore balance