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Sterilization of Capital Inflows and Balance of Payments Crises

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Abstract

Large capital in‡ows 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 in‡ows. Sterilization increases the domestic interest rate, exacerbating the in‡ows and widening the …scal de…cit. Exploiting these facts, this is the …rst paper to link the sterilization e¤orts with BOPC in a general equilibrium model. We analyze two situations that result in increased capital in‡ows and show that sterilization is not the best policy response to them.

First is the case of an economy with a …scal de…cit that leads to a loss of reserves and a BOPC. It is shown that if the Central Bank tries to sterilize capital in‡ows, the current account de…cit increases and the BOPC is brought forward.

Second is the case of an economy facing a temporary decrease in the international interest rate. We show that an attempt to sterilize capital in‡ows leads the economy to a BOPC. We argue that this case is relevant to understand the events leading to the 1994 Mexican currency crisis. If the domestic interest rate is allowed to converge to the international one, as in a Currency Board, BOPC are avoided.

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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 in‡ows compared to the 80's, and the repeated balance of payments crises (BOPC) associated with the sudden reversals of these ‡ows.

Capital ‡ows 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 ‡ows 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, Leiderman and Reinhart, 1994).

The volatility of capital ‡ows has also increased. The IMF has estimated that the volatility of portfolio ‡ows to Western Hemisphere and some Asian developing countries has tripled from the 80's to the 90's. Sudden swings in capital ‡ows 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, distinguishing between BOPC caused by fundamentals -"…rst generation models"-, BOPC caused by self-ful…lling prophecies -"second-generation models"- (see Flood and Marion, 1998, for a survey of these models), and BOPC caused by contagion (Eichengreen et al., 1996).

A separate but not totally unrelated strand of literature deals with the causes and consequences of the surge in capital ‡ows 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/…scal/exchange rate policies to face it.

Calvo, Leiderman and Reinhart (1993 and 1994) highlighted the importance of external factors in the renewal of capital ‡ows to Latin America at the beginning of the 90's. Capital ‡ows 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 ‡ows 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), 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. Kaminsky (1997), for example, finds that appreciation of the real exchange rate is the best univariate predictor of future currency crises (see Buscaglia and Gasha, 2000).

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 (Montiel and Reinhart, 1997). 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.

There is, though, a lot of controversy over the effectiveness and convenience of capital inflows sterilization. There is no consensus on whether sterilization is effective or not from a theoretical point of view, and the empirical results are mixed for developed countries.[1] Nevertheless, the empirical literature finds that sterilization has been effective for developing countries (Cumby and Obstfeld, 1983).

Moreover, at least three objections can be placed to the sterilization of capital inflows:

[1] See Backus and Kehoe (1989). Also see Lewis (1994) for a recent discussion of the rationale of sterilized intervention and some empirical results.

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 in‡ows 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 …scal de…cits.

This is the …rst paper to model in a general equilibrium framework the relationship between the sterilization of capital in‡ows and balance of payments crises.[2] We exploit the fact that the sterilization of capital in‡ows increases the domestic interest rate and the …scal de…cit, and we analyze two experiments that result in increased capital in‡ows to an economy that …xes the exchange rate, showing that sterilization is never the best policy response to those in‡ows. These experiments are simpli…cations of two situations that typically derive in increased capital in‡ows in emerging markets: a …scal de…cit, and temporary reductions of international interest rates.

First we consider the case of an economy with a …scal de…cit that leads to a loss of reserves and a BOPC. It is shown that if the government tries to sterilize capital in‡ows, the current account de…cit (CAD) increases and the BOPC is brought forward. Such a situation of a high …scal de…cit and sterilization of capital in‡ows took place in Brazil in 1995 and 1996.

Second we 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 in‡ows leads the economy to a BOPC. The mechanics are the following. The sterilization of capital in‡ows increases the domestic debt and the central bank's de…cit in the period of low international interest rates. When international interest rates rise, the sterilization of capital out‡ows

[2] Calvo (1996) presents a political-economy model showing that after sterilization of capital in‡ows the domestic debt grows and thus the temptation to raise in‡ation tax increases.

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 e¤ort 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.

We also show that in the context of perfect foresight and perfect capital mobility sterilization is ine¤ective in the sense that it does not reduce the current account de…cit.[3] 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.[4]

The second 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-…nancial public sector de…cit 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 in‡ows with short-term bonds (more on this in Section 2.3), and later did the opposite (sterilization of capital out‡ows) when the international interest rate started to rise in 1994, months before the crisis.

On the empirical side we discuss some previous evidence on sterilization e¤orts as well as providing some of our own estimates. We …nd that, although somewhat blurred, external factors continue to be important in the determination of capital ‡ows to emerging economies.

The rest of the paper is organized as follows. In Section 2 we provide some empirical …ndings on the determinants of capital ‡ows to developing countries, on its e¤ects, and on some sterilization attempts. In Section 3 the theoretical model is described. In Section 4 we

[3] Or the appreciation of the real exchange rate, as could be easily proved introducing home goods in the model. This was …rst noted by Mundell (1968)

[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 e¤orts of the Central Bank to sterilize capital out‡ows at the time of the attack.

show that an attempt to sterilize capital in‡ows in an economy with unsound monetary/…scal policies will only bring forward the timing of the BOPC. In Section 5 we show that an attempt to sterilize capital in‡ows 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 6 concludes.

2 Empirical Motivation

In this section we present some empirical evidence on the determinants of capital in‡ows to developing countries and on some sterilization episodes. The main results, which constitute the background to the experiments presented below, are that:

- The timing and magnitude of capital in‡ows to developing countries are determined mainly by events in developed nations,

- Sterilization has been the most common response to capital in‡ows, and

- Countries that sterilized capital in‡ows had higher interest rates and could not avoid running current account de…cits.

2.1 The Determinants of Capital Flows to Developing Countries

The early empirical literature on the determinants of capital ‡ows to developing countries concentrated on whether the surge of the 90's was originated on events taking place in developed or in developing countries (see Montiel and Reinhart, 1999).[5]

Calvo et al. (1993) emphasized the role of external factors during the early 90's. They performed a principal components analysis taking changes in international reserves and the real exchange rate as monthly proxies of capital ‡ows for 10 Latin-American countries. These series showed a high degree of co-movement in the early 90's. In addition, the …rst

[5] We call "external factors" to economic and non-economic events taking place outside developing countries (i.e., in developed countries).

principal component of each series displayed a high correlation with the US interest rate, this being considered as evidence of the importance of external factors. Later research extended this analysis in several directions. Results indicate that although domestic factors have become more important in recent years, external factors continue to be highly relevant to the determination of the "timing and magnitude" of capital flows to developing countries (Montiel and Reinhart, 1999).[6]

In this subsection we update -with some modifications- the methodology of Calvo et al. (1993) to analyze the determinants of capital inflows to nine developing countries from 1990 to 1998. To that purpose, we apply the principal components technique to quarterly data of capital inflows from the IMF.[7] Once we extract the principal components of the capital flows series, we analyze to what extent they are determined by external factors. The results can be seen in Table 1. The general idea is that if few principal components explain a big part of the common variability of capital flows to these countries, and if the principal components are at the same time highly correlated with some external variable like the US interest rate, then external factors can be considered as important determinants of capital flows to the countries under analysis.

In particular, researchers usually use liquidity conditions in G-7 countries as the most important external factor. More recently, it has been argued that interest rates in developed countries alone are not enough to extract conclussions about global liquidity conditions (see IMF, 1999). This led us to construct a global liquidity variable (GLV) that measures to which extent monetary growth exceeds that of nominal GDP in developed countries. A high value of this variable indicates accommodative monetary conditions.[8]

Our results indicate that there is a high degree of comovement in capital inflows among

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[6] The principal component analysis allows to assess the statistical importance of common factors in the variability of several variables. For an explanation of the methodology, see Dhrymes (1974)

[7] They are: Argentina, Brazil, Chile, Mexico, Peru, Indonesia, Korea, Phillippines, and Thailand.

[8] The countries included are France, Germany, Japan, United Kingdom, and the US. All the variables are weighted by the GDP of the country, measured in US Dollars at the 1-year average exchange rate. See IMF (1999) for details.

countries in the same region. The …rst two principal components account for 70 percent and 85 percent of the commovement of capital ‡ows in Latin America and emerging Asia, respectively. Moreover, these principal components show a positive correlation with the global liquidity variable.

Table 1. Principal Components Analysis of Capital In‡ows

	Latin America	Asia
1st principal component	0.46	0.65
2nd principal component	0.24	0.20
Correlation of 1st principal component with GLV	0.40	0.21

Evidence on the decreased importance of external factors in recent years is inconclusive. If we divide the sample in two, the …rst of which reaches up to the fourth quarter of 1994, the …rst two principal components decrease in Asia but increase in Latin America from the …rst period to the second.

In Ades, Buscaglia and Masih (2000), we estimate a generalized variance decomposition (GVDC) to quantify the determinants of capital ‡ows to six of the biggest emerging markets. There we …nd that global liquidity is one of the key drivers of total capital ‡ows and, specially, of portfolio ‡ows. Moreover, we …nd no evidence that global liquidity has decreased its importance as a driver of capital ‡ows in the second half of the 90's. Overall, we can conclude that external factors continue to be relevant to the determination of capital in‡ows to emerging countries.

2.2 Consequences of Sterilization

Sterilized intervention has been the most common response to the capital in‡ows' surge during the 90's among developing countries (Calvo et al., 1994). Six out of eight Latin-American and Asian developing countries included in Montiel and Reinhart's (1997) study maintained extended sterilization policies, as can be seen in Table 2.

Table 2. The Sterilization Index[9]

	Argentina	Brazil	Chile	Colombia	Indonesia	Malaysia	Mexico	Thailand
90	0	0	2	0	0	0	1	2
91	0	0	0	2	2	1	1	2
92	0	1	1	0	2	2	1	0
93	0	1	1	0	1	2	1	0
94	0	2	1	0	1	0	0	0
95	0	2	1	0	0	1	0	2
96	0	2	1	0	0	1	0	0

Source: Montiel and Reinhart (1997)

The empirical evidence suggests that countries that sterilized capital in‡ows registered higher interest rates than countries that did not. Reinhart and Reinhart (1998) …nd that the rise in interest rates was pronounced in countries that sterilized and that in all cases short-term interest spreads remained relatively high compared to those of countries that did not sterilize.

Moreover, Montiel and Reinhart (1997) found that "an intensi…cation in the degree of monetary sterilization is associated with an increase in the volume of aggregate capital ‡ows, irrespective of the estimation technique employed", and that the increase takes the form of short-term capital ‡ows.

In Table 3 we present …gures of capital in‡ows as percent of GDP for some developing countries. Casual observation of this table in conjunction with Table 2 supports the idea that, at least, sterilization does not reduce the magnitude of capital in‡ows.

Table 3. Capital Flows as a Percent of GDP

[9] This index takes a value of 0 if there is limited contraction in domestic credit, a value of 1 if there is a more important e¤ort to sterilize through open market operations, and a value of 2 if sterilization is in large scale or is accompanied by increases in banks' reserves requirements.

	90	91	92	93	94	95	96
Argentina	-0.8	1.3	4.6	4.7	3.8	1.4	3.4
Brazil	1.0	0.0	2.6	1.9	1.3	4.3	4.4
Chile	10.0	2.4	0.7	8.0	8.8	1.7	6.7
Colombia	-0.1	2.1	0.0	4.8	4.4	6.2	7.1
Costa Rica	3.8	4.1	6.3	8.0	4.3	3.6	4.5
Mexico	4.5	7.1	7.1	7.3	2.4	4.0	1.2
Indonesia	4.7	0.8	1.3	2.4	0.8	2.5	2.8
Malaysia	4.2	11.7	14.9	16.8	1.8	8.5	6.4
Phillippines	4.0	4.9	1.2	3.7	6.4	5.5	9.2
Thailand	11.4	12.7	8.9	10.0	8.8	13.5	9.3

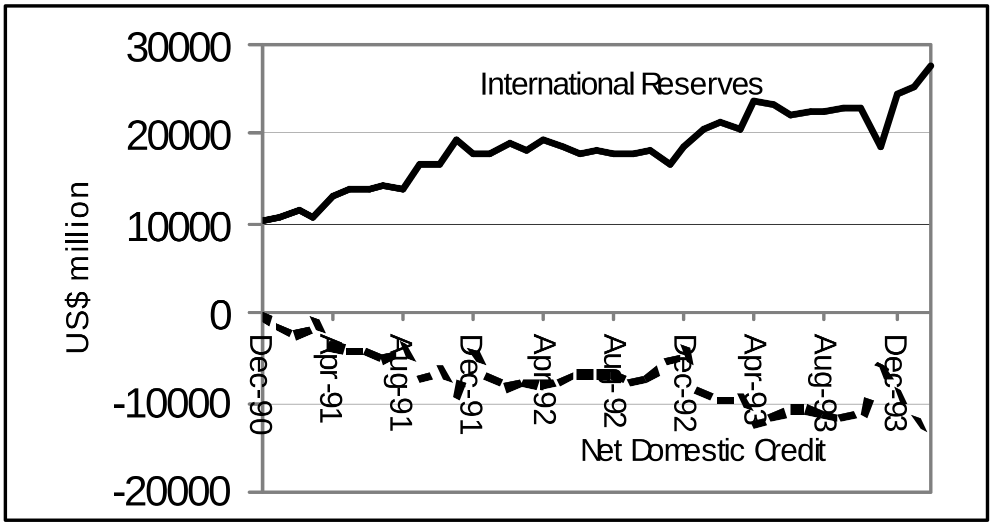
Source: IMF. World Economic Outlook

2.3 The Mexican Case

Many countries that experienced BOPC during the 90's had previously sterilized capital in‡ows (see Table 2). They include Mexico during 1993 and Brazil in 1995 and 1996. At a time in which investors' con…dence in developing countries is increasing again, some countries as Korea are sterilizing capital in‡ows massively. Here we emphasize the Mexican case, as this pattern of sterilization of capital in‡ows during times of low international interest rates is the one that we formalize in Section 5.

In Mexico, between December 1992 and February 1994 Net Domestic Credit of the Central Bank decreased by $ 9.9 billion, while International Reserves increased by a similar …gure and the Monetary Base remained almost unchanged (Figure 1). At the same time, government short-term debt (CETES, Bondes and Tesobonos) outside the central bank increased from $ 15.6 billion to $ 32.9 billion. Interest rates were kept high and the current account de…cit was 5.9 percent of GDP in 1993.

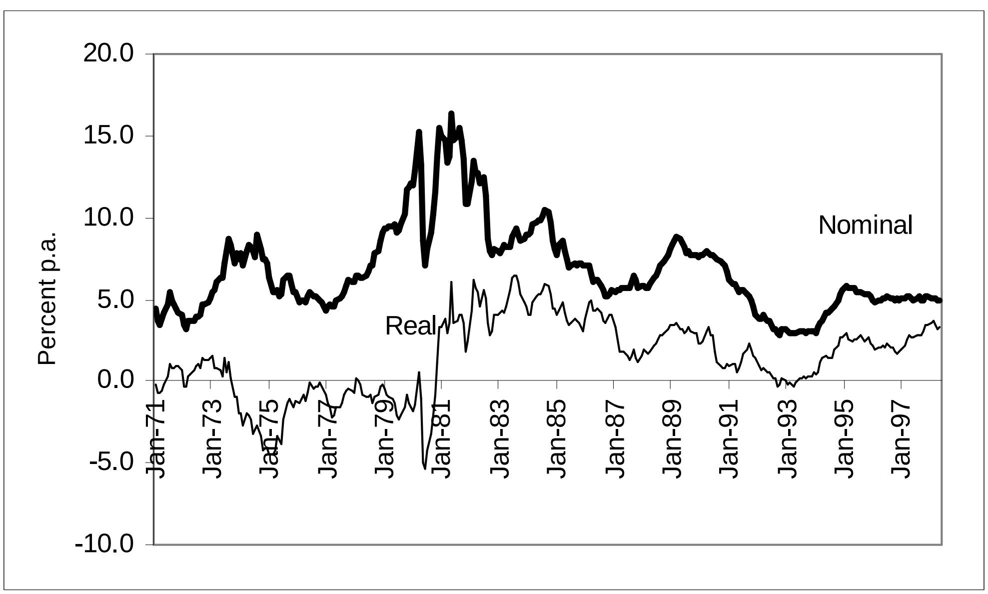
Figure 1. Mexico: International Reserves and Net Domestic Credit



Source: Central Bank of Mexico

This took place during a period of low international interest rates, as can be seen in Figure 2. When the US interest rate started to increase in February of 1994, the Mexican Central Bank started to sterilize capital out‡ows, which led to a decrease in international reserves throughout 1994.

Figure 2. US Short-Term Interest Rate



Source: Citibase

3 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 national representative agent. The representative agent has also access to an interest bearing international asset.

3.1 The Households

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

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

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

Assume that the HH preferences are of the CEIS type[10]

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

Households can invest in three types of assets:

i. domestic money, m_t

[10] We adopt Kumhof's functional forms. Note that $\delta > 0$.

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).[11]

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 $0 < \alpha < 1$:

We assume that L has a CES form

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

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 $p^* = 0$, so $\dot{p} = \varepsilon$; where ε is the rate of devaluation of the exchange rate (equal to the rate of inflation). Then total wealth evolves according to

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

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

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.[12] 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. $r + \pi > 0$. The oportunity cost of money balances has to be strictly positive. This is true even when $\pi = 0$, as $r > 0$.

ii. $r + \pi > i$. 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.[13]

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

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

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 and then check that the solution satisfies the sufficient conditions for this to be true. Let λ be the multiplier of constraint (4) in the Hamiltonian.

The FOC with respect to money holdings and domestic bond holdings are respectively:

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

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

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

and

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

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

$$\frac{Ld_t}{Lm_t} = \frac{r + \varepsilon_t - i_t}{r + \varepsilon_t} \tag{7}$$

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

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

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

$$d_t = \frac{\alpha c_t}{A\left(\omega(\frac{m_t}{d_t})^{\frac{\sigma-1}{\sigma}} + (1-\omega)\right)^{\frac{\sigma}{\sigma-1}}} \tag{9}$$

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

and,

$$m_t = \frac{\alpha c_t}{A\left(\omega + (1-\omega)(\frac{d_t}{m_t})^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}} \tag{11}$$

$$= \frac{\alpha c_t W\Phi(X_t)}{L(W\Phi(X_t);1)}. \tag{12}$$

In order to facilitate the exposition of the following sections, it is very 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**.[14]

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

Define (total domestic) liquid assets as

$$l_t \equiv m_t + d_t \tag{13}$$

Then (see Appendix A for a proof)

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

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 (7)) and so money, being more productive at the margin, varies less than government debt.

A summary of these results is presented in Table 4

Table 4. Substitution and Level Effects on Domestic Assets' Demand

effect on $\Rightarrow$	m	d	l	$\frac{m}{d}$
increase in π or r (substitution effect)	$\uparrow$	$\downarrow$	$\downarrow$	$\uparrow$
increase in i (substitution effect)	$\downarrow$	$\uparrow$	$\uparrow$	$\downarrow$
increase in c (level effect)	$\uparrow$	$\uparrow$	$\uparrow$	

3.2 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:

$$g_t + \bar{i} d_t + \dot{k}_t = r_t k_t + \pi_t (m_t + d_t) + \dot{d}_t + \dot{m}_t \tag{14}$$

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 (14) 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's change (RHS). Moreover, at some points in time there can be discrete swaps of domestic money or bonds for international reserves.

We assume that there is a lower bound on the Central Bank's international reserves, below which it will abandon the exchange rate peg. Assume for simplicity that this bound is zero.

$$k_t \geq 0 \quad \forall t \tag{15}$$

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 the government initially runs consistent monetary, fiscal and exchange rate policies, and that it pegs the exchange rate ($\varepsilon = 0$): From equations (5), (9), and (11) we can see that for ε; r and i fixed, consumption and the demand of money and domestic bonds will be constant (implying that $\dot{d}_t = \dot{m}_t = 0$). From (14) we can see that $\dot{k}_t = 0$ if and only if:

$$rk_t = g_t + \bar{i}d_t \tag{16}$$

so the government needs a primary surplus ($g < 0$) sufficient to cover net interest payments in order to achieve global fiscal balance.[15]

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

3.3 The Aggregate Economy

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

$$f_t = b_t + k_t \tag{17}$$

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

$$\dot{f}_t = rf_t + y - c_t \tag{18}$$

which means that the accumulation of net foreign assets is equal to the current account balance. Integrating (18) forward and imposing the transversality condition $\lim_{t \to \infty} f_t e^{-rt} = 0;$ we get the economy's lifetime resource constraint

$$f_t + \frac{y}{r} = \int_t^{\infty} c_s e^{-r(s-t)} ds \tag{19}$$

implying that the present value of consumption (RHS) has to be equal to the present value of resources (LHS). Note that from equation (18) we can also calculate the constant level of consumption that keeps the net foreign assets holdings unchanged from that period on

$$c_t = rf_t + y \tag{20}$$

3.4 Level Effects

Before continuing it is worth to clarify the conditions under which changes in r, "; or i bring **level** effects to the demand of domestic assets, in addition to the already explored substitution 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 former arise only when r changes, as is evident from equation (19). The latter arise when the effective price of consumption is modified unevenly through time.

The term between brackets at the RHS of equation (5) is the effective price of consumption, q_t

$$q_t(I_t; i_t) = \left[1 + \frac{\alpha}{L m_t}(r + \varepsilon_t) \right] \tag{21}$$

which increases when I_t increases (i.e.: when r or ε increase), and decreases when i_t increases

$$\left.\frac{\partial q_t}{\partial I_t}\right|_i = \frac{\frac{\alpha}{L_m} - \alpha I_t L_{mm} \Phi'(X_t)(\frac{\partial X_t}{d I_t})}{(L_m)^2} > 0 \tag{22}$$

$$\left.\frac{\partial q_t}{\partial i_t}\right|_I = \frac{-\alpha I_t L_{mm} \Phi'(X_t)(\frac{\partial X_t}{d i_t})}{(L_m)^2} < 0 \tag{23}$$

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

$$c_t = (r f_0 + y) \frac{\left[\frac{1}{r \int_0^{\infty} \frac{e^{-rt} dt}{\left[1 + \frac{\alpha}{L d_t}(r + \varepsilon_t - i_t)\right]}} \right]}{1 + \frac{\alpha}{L d_t}(r + \varepsilon_t - i_t)} \tag{24}$$

where Calvo and Vegh call the last term on the RHS the Marginal Propensity to Consume (MPC) out of permanent income. If, for example, the effective price of consumption remains constant forever, the MPC would be equal to one every period and consumption would remain constant forever.

Unanticipated fluctuations in r (temporary or permanent) bring wealth effects, as they modify the lifetime resource constraint of the economy (equation (19)). 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 accross time (i.e., change the MPC in (24)). With an exogeonous fiscal constraint, permanent changes in i might be able to bring an intertemporal substitution effect, a result that differs from Calvo and Vegh (1990). We explore this below.

A summary of these results is presented in Table 5

Table 5. Wealth and Intertemporal Substitution (IS) Effects

	permanent	temporary
change in r	wealth & IS	wealth & IS
change in i or ε	IS only	IS only

Finally, lets specify a result that will be used in Section 5.1.

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 (6), note that

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

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

$$\Leftrightarrow \quad \left.\frac{\partial\left(\frac{1}{Ld}\right)}{\partial l_t}\right|_i > - \left.\frac{\partial\left(\frac{1}{Ld}\right)}{\partial i_t}\right|_l$$

$$\Leftrightarrow \quad -\frac{i_t}{l_t} > -1$$

$$\Leftrightarrow \quad i_t < l_t$$

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

4 Sterilization in an Unbalanced Economy

In this …rst experiment we analyze the consequences of sterilization of capital in‡ows when the Central Bank follows an exchange rate policy that is inconsistent with the …scal/monetary regime (see Calvo, 1987 and Kumhof, 1998).

We start with this experiment for two reasons. The …rst one is empirical, as this seems to have been the situation of Brazil in 1995-96, when the Central Bank's debt increased by more than $ 50 billion due to the sterilization e¤ort, while the overall …scal de…cit exceeded 5 percent of GDP. [16] The second reason is that the main results of this paper, derived in Section 5, build in part from the analysis presented here.

More explicitly, we analyze a government that initially …xes the exchange rate and the interest rate for domestic bonds, running a primary surplus equal to its net interest payments (overall …scal balance). At period $t=0$, however, the primary surplus is transformed into a primary balance, running then an overall …scal de…cit that is fully monetized:

Even though the government tries to reduce in‡ation by pegging the exchange rate, it implicitly gives a higher priority to an expansionary …scal policy. Real money demand is constant during the exchange rate peg and so the full monetization of the de…cit implies that reserves shrink over time. The peg will ultimately have to be abandoned. We call "transition" to the period that goes from the elimination of the primary surplus ($t=0$) to the BOPC ($t=T$). After the currency crisis, …scal balance is achieved by means of the in‡ation tax.

Given that there is perfect foresight, HH fully anticipate that their consumption will be taxed in the future (via an increase in the e¤ective price of consumption) and hence increase it in the transition, leading the economy to run a current account de…cit during that period. This pattern, called the "temporariness hypothesis", has been extensively documented and modeled (see Calvo, 1986, 1987 and Uribe, 1997).

We model the sterilization e¤ort as a permanent increase in the interest rate paid on

[16] Brazil …nally experienced a BOPC at the beginning of 1999.

domestic bonds (at the same time that the primary surplus is eliminated) , given that it will lead to an increase in their demand. The objective of the government would be to sterilize the capital inflows and hence to eliminate the increase in monetary aggregates, aggregate demand and the deterioration of the real exchange rate (see Calvo, 1986; Uribe, 1997b, and Mendoza and Uribe, 1999).[17]

In Section 4.1 we find the timing of the speculative attack when there is no sterilization of capital inflows, following Kumhof (1998). In Section 4.2 we show that sterilization brings forward the timing of the BOPC. In Section 4.3 we analyze the welfare implications of both policies.

4.1 The Speculative Attack without Sterilization

Note that we can distinguish three periods [18]:

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

The government runs consistent monetary, fiscal and exchange rate policies.

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

The government changes the fiscal policy at t=0, setting $g_1 = 0$: An overall fiscal deficit results (from the domestic debt interest payments) and is fully monetized. This monetary/fiscal policy is inconsistent with the exchange rate policy, given that the exchange rate remains fixed. This inconsistency leads to a collapse of the exchange rate regime at $t = T$:

3- Period 2 ($t \geq T$)

After the collapse, the exchange rate starts floating.

We still have to show that these policies lead the economy to a collapse of the exchange

[17] Though we do not have a non-tradable goods sector in our model, it is easy to see that during the transition the increase in domestic demand would lead to an appreciation of the real exchange rate had we included it. Calvo and Vegh (1990) argue that only temporary increases in the domestic interest rate are worth to analyze. But in our case the sterilization effort implies a higher devaluation rate after the collapse of the peg (more on this below), and so it is natural to think that the increase in the domestic nominal interest rate is permanent.

[18] We will use subscripts 0, 1 and 2 for all the variables in the respective periods.

rate at t=T. This is done next in two steps, following Kumhof (1998). First we show that if this policy results in a loss of reserves that makes the Central Bank hit the lower bound set in equation (15), then the devaluation rate (ε_2) 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).

4.1.1 We want to show that if k=0 after some time (after t=T), then $\varepsilon_2 > 0 \; \forall t > T$.

Note that k=0 implies $\overset{\varepsilon}{k}_t = 0$ after t=T, which from the consolidated government budget equation will hold if and only if $\Psi(\varepsilon_2) \equiv \varepsilon_2(m_2 + d_2) - \beta d_2 = 0$. Then:

$$\varepsilon_2 = \frac{\beta d_2}{m_2 + d_2} = \frac{\beta}{\frac{m_2}{d_2} + 1} \tag{25}$$

From equation (8) we can see that when r and β are constant, the ratio $\frac{m_2}{d_2}$ is solely a function of ε; and $\frac{\partial \left(\frac{m_2}{d_2}\right)}{\partial \varepsilon} > 0$. Also note that Ψ is continuous and that $\Psi(\varepsilon_2 = 0) = -\beta d_2 < 0$ and $\Psi(\varepsilon_2 = \beta) = \beta m_2 > 0$. This implies that equation (25) has a unique strictly positive solution ■

4.1.2 Now we want to show that this policy leads to a depletion of reserves.

The increase in the devaluation rate from period 1 to period 2 implies that consumption falls in period 2, as the effective price of consumption increases. To see this, specialize equation (5) to period 1 and period 2

$$\frac{c_2}{c_1} = \frac{\left(1 + \alpha \frac{r}{L_{m1}}\right)^{\delta}}{\left(1 + \alpha \frac{r + \varepsilon_2}{L_{m2}}\right)^{\delta}} = Z < 1 \tag{26}$$

If the change in fiscal policy is unsustainable, then $c_1 > c_2$ (see Calvo, 1986). The jump in consumption brings a positive level and no substitution effect on the demand of domestic assets at time 0, unambiguously increasing the stock of domestic bonds.

If the combined effects were sustainable then $\varepsilon_2 = 0$ and the consumption and asset demands would not change. But this is a contradiction, since the budget was already balanced at g_0 and d_0. ∎

4.1.3 Evolution of reserves and timing of the BOPC

As usual in BOPC models, we track the evolution of reserves over time and then determine the optimal timing of the speculative attack, defined as the moment in which all remaining reserves are taken by the market and the Central Bank abandons the peg.

i. At time 0, as $\varepsilon_0 = \varepsilon_1 = 0$, there is only a level effect (no substitution effect).[19] From (12), (10), and the fact that $c_0 = rf_0 + y$ we get:

$$\begin{aligned} \Delta k_0 &= \Delta m_0 + \Delta d_0 \\ &= \frac{W\Phi(X_0)+1.}{L\left(W\Phi(X_0),1\right)}\alpha(c_1 - c_0) \\ & \frac{W\Phi(X_0)+1.}{L\left(W\Phi(X_0),1\right)}\alpha(c_1 - rf_0 - y) \end{aligned} \tag{27}$$

$(\Delta k_0 > 0)$

ii. From time 0 onwards, as consumption is constant and the domestic and international interest rates do not change, $\dot{d}_t = \dot{m}_t = 0$. Using (10), (14) can be reexpressed as:

$$\dot{k}_t = rk_t - \frac{\beta\alpha c_1}{L\left(W\Phi(X_1),1\right)}$$

Therefore, at $t=T$,

$$k_T = (k_0 + \Delta k_0)e^{rT} - \frac{\beta\alpha c_1}{L\left(W\Phi_1,1\right)}\left(\frac{e^{rT}-1}{r}\right) \tag{28}$$

iii. To determine the timing of the speculative attack, we need to calculate the level of reserves needed to exactly face the jump in assets' demand that takes place at $t=T$, without

[19] We follow Kumhof's (1998) decomposition in level and substitution effects.

violating the restriction imposed in equation (15). We decompose the change in assets' demand at t=T in level effects and substitution effects. [20]

The **level effect** can be computed as:

$$\begin{aligned} \Delta k_T^{lev} &= \Delta m_T^{lev} + \Delta d_T^{lev} \\ &= \alpha \Delta c \left(\frac{W\Phi_1 + 1.}{L(W\Phi_1; 1)} \right) \end{aligned}$$

To find the value of $\Delta c = c_1 - c_2$ we use equation (18) and solve it for t=0 to t=T. The result is:

$$rf_T = e^{rT}(rf_0 + y - c_1) - y + c_1$$

At t=T, consumption jumps to c_2 and reserves are exhausted. Its permanent level is hence given by equation (20). Then

$$c_1 - c_2 = e^{rT}(c_1 - y - rf_0)$$

and

$$\Delta k_T^{lev} = \alpha e^{rT}(c_1 - y - rf_0) \left(\frac{W\Phi_1 + 1.}{L(W\Phi_1; 1)} \right) \tag{29}$$

The **substitution effect** is equivalent to

$$\Delta k_T^{sub} = \alpha c_2 \left(\frac{W\Phi_1 + 1.}{L(W\Phi_1; 1)} - \frac{W\Phi_2 + 1.}{L(W\Phi_2; 1)} \right) \tag{30}$$

where the subscripts on the function Φ stand for the period.

[20] Note that reserves fall at t=T, but we invert terms in order to have $\Delta k_T > 0.$

The total change in Central Bank's reserves at time $t = T$ is $\Delta k_T = \Delta k_T^{sub} + \Delta k_T^{lev}$. The condition to find T is that $k_T - \Delta k_T = 0$. Using equations (28), (29) and (30), this condition is equivalent to

$$e^{rT} = \frac{\frac{\beta \alpha c_1}{L(W\theta_1;1)} - \alpha c_2 r S}{\frac{\beta \alpha c_1}{L(W\theta_1;1)} - r k_0} \tag{31}$$

where S is the expression between parenthesis in equation (30). Note that S is greater than zero, given that $\theta_2 > \theta_1$ and the way in which we defined it. [21] From (31) we get another expression for the relation between c_2 and c_1:

$$c_1 - c_2 = (c_1 - y - r f_0) \frac{\frac{\beta \alpha c_1}{L(W\theta_1;1)} - \alpha c_2 r S}{\frac{\beta \alpha c_1}{L(W\theta_1;1)} - r k_0} \tag{32}$$

4.2 The Speculative Attack under Sterilization

In this subsection we want to show that if at time 0 the government raises the interest rate on domestic bonds to $\bar{i}'$ ($\bar{i}' > \bar{i}$) in addition to eliminating the primary surplus, the collapse of the exchange rate is brought forward compared to the no sterilization equilibrium.[22]

We show that not only the BOPC occurs earlier, but that under perfect foresight and perfect capital mobility the sterilization of capital inflows is ultimately unsuccessful in reducing the current account deficit.

Proposition 2 *A permanent increase in the interest rate on domestic bonds at $t = 0$ brings forward the timing of the Balance of Payments Crisis.*

Proof. See Appendix B. ■

[21] Otherwise we would be contradicting our findings of section 3.1.

[22] Some key variables in this new experiment will have an apostrophe.

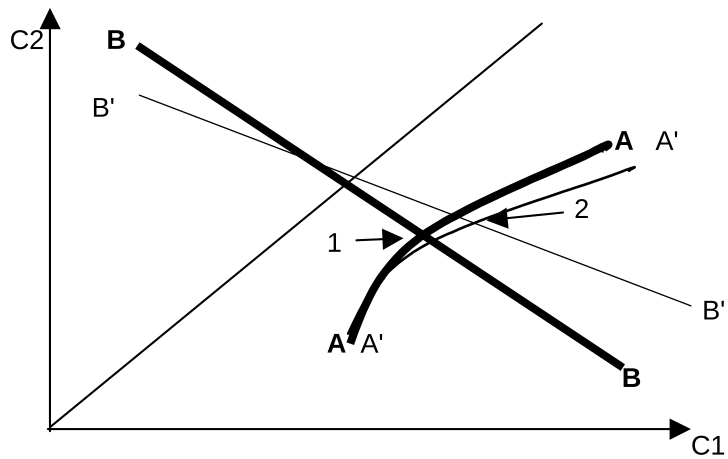
The intuition behind this proposition is that by raising the interest rate at t=0, the overall …scal de…cit increases further and thus the depletion of reserves occurs earlier. The …scal de…cit increases because of the higher interest rate and the higher stock of bonds outstanding.

In addition to the change in the …scal de…cit, we have to take care of the changes in assets (and thus in reserves) at times 0 and T^0. The interest rate hike generates a substitution e¤ect that increases international reserves at t = 0, but it also increases the devaluation rate ("$_2$) needed to restore …scal balance after the BOPC. The increase in the devaluation rate will make the negative substitution e¤ect higher than it was originally at the time of the speculative attack.[23] Finally, note that the increase in "$_2$ reduces the e¤ective price of consumption at period 1 (q_1) with respect to the average, thus increasing consumption during the transition (and reserves at t = 0); but, for the same reason, the fall in consumption and reserves is higher at $t = T^0$.

The equilibria with and without sterilization can be graphically described as follows. Equations (26) and (32) constitute, for a given value of T, a system of equations that can be solved for the values of c_1 and c_2. In Figure 3, the curve AA describes the locus of c_1 and c_2 that satisfy equation (26), while the curve BB describes the locus of c_1 and c_2 that satisfy equation (32) when there is no sterilization of capital in‡ows (see Calvo, 1987b for the details). A decrease in T reduces the slope of BB, not changing AA, while an increase in "$_2$ decreases the slope of AA. The result is an increase in both c_1 and c_2. Points 1 and 2 describe the equilibria without and with sterilization of capital in‡ows, respectively.

Figure 3. Consumption with and without Sterilization

[23] Recall that we are comparing this experiment in which the government eliminates the primary surplus and raises the interest rate at time 0 with the previous one, in which only the primary surplus is eliminated.



An alternative way to think about this result is to see that, starting from a steady state position, any permanent increase in the domestic interest rate deteriorates the ...scal position (all else equal). Although international reserves initially increase, the ...scal de...cit leads to a BOPC in ...nite time. The details are presented in Appendix C. [24]

Proposition 3 The increase in the interest rate on domestic bonds at time t=0 increases the current account de...cit during the transition compared to the no-sterilization case.

P roof. This follows from the fact that the interest rate hike increases the devaluation rate required to maintain ...scal balance after the BOPC, and thus it lowers the e¤ective price of consumption in the transition with respect to the average e¤ective price of consumption. ■

The intuition behind this is that as agents foresee that the BOPC will take place earlier (i.e. their consumption will be taxed earlier) they increase consumption even more during the transition and thus the current account deterioration is bigger. This result is similar to the one derived by Calvo (1986) when investigating the e¤ects of increasing the "degree of temporariness" of an exchange rate based stabilization program and is consistent with the empirical ...ndings for emerging markets (Montiel and Reinhart, 1997)

[24] I thank Martín Uribe for making me note this.

Proposition 4 At the speculative attack, bonds and not money are primarily changed for foreign reserves.

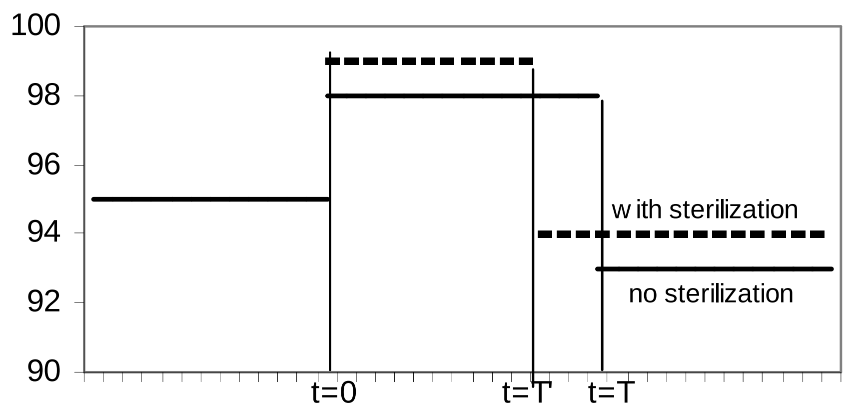
P roof. This follows from the sign of the substitution e¤ect for money and bonds when the devaluation rate increases. As discussed in Section 3.1, it is positive for the former and negative for the latter. The level e¤ect makes the demand of both decrease. ■

As discussed in Calvo (1995), one salient featue of some recent BOPC is that speculative attacks are concentrated in the domestic bond market. We have derived this e¤ect without the need to introduce banks in the analysis, as Kumhof (1998) does. As in Kumhof's analysis, the attack takes place in the bond market because the government keeps the nominal interest rate i constant at time $t = T$, when the devaluation rate becomes positive, decreasing the relative real return of domestic bonds.

4.3 Discussion and Welfare Analysis

The attempt to sterilize capital in‡ows during the transition period does not deliver the desired results, as is brings forward the timing of the BOPC and generates a bigger current account de…cit. One possible pattern of consumption in both experiments can be seen in Figure 4. Note that although the domestic interest rate hike increases consumption in periods 1 and 2, the timing of the crisis is brought forward and so consumption falls earlier to the low post-crisis level.

Figure 4. Consumption Levels



Welfare effects of the sterilization attempt are cannot be derived analytically, as first noted by Calvo (1987b) in another context. This would not be the case were we comparing a no-BOPC equilibrium path with any path that entailed a BOPC. The former would be the one that a central planner would choose, with constant consumption over the planning horizon, and so the latter would always be welfare decreasing. But in our case we are comparing two crisis paths, so results should derived numerically.

To conduct the welfare analysis we calibrate the model to match certain aspects of major emerging Latin-American and Asian economies, as international reserves of approximately 14 percent of GDP and gross external debt of 45 percent of GDP. The details can be seen in Appendix D. We then calculate the timing of the currency crisis after the elimination of the primary surplus at $t=0$ under no sterilization and under sterilization, for different initial values of the domestic interest rate.[25]

We measure the welfare costs associated with the paths leading to a BOPC with and without sterilization by the fraction of the steady state consumption that households would be willing to give up in order to be indifferent between the corresponding constant sequences

[25] As explained in Appendix D, we use $\delta = 0.1$ in our calculations. Many authors have suggested, however, that the value of δ in lower and upper middle income developing economies is substantially higher, ranging from 0.2 to 0.62 (see Ogaki et al., 1996). In future versions we will include simulations with higher values for δ; and expand the range of parameters for which the computations are performed.

of consumption and the equilibrium ones in the experiment under consideration (in an analogous way to Lucas, 1987).

That is, we look for the λ such that

$$U(c_0(1-\lambda)) = U(c_t)$$

where total welfare under no BOPC is given by

$$U(c_0) = \left[\frac{c_0^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}}\right]\frac{1}{r_0}$$

and total welfare in the case of a BOPC under sterilization and no sterilization can be calculated by replacing the appropriate values of c_1, c_2 and T in

$$U(c_t) = \frac{c_1^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}}\left[\frac{1-e^{-r_0T}}{r_0}\right] + \frac{c_2^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}}\left[\frac{e^{-r_0T}}{r_0}\right]$$

Finally, we calculate whether λ is bigger under sterilization or under no sterilization, where λ is given by

$$\lambda = 1 - \left[c_1^{1-\frac{1}{\sigma}}\left(1-e^{-r_0T}\right) + c_2^{1-\frac{1}{\sigma}}\left(e^{-r_0T}\right)\right]^{\frac{\sigma}{\sigma-1}}[c_0]^{-1}$$

Preliminary results indicate that welfare decreases with sterilization in all cases, as can be seen in Table 6.[26]

Table 6. Timing of the BOPC and Welfare Effects

	$i_0 = 3\%$	$i_0 = 4\%$
T (no sterilization)	17.70	7.08
T' (sterilization)	16.68	6.98
λ (no sterilization)	0.001 %	0.0002 %
λ (sterilization)	0.006 %	0.0003 %

[26] In both cases the increase in domestic interest rate analyzed equals 0.1 percentage points. Note also that sterilization brings forward the timing of the BOPC in all cases, as expected.

5 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 temporary decrease in the international interest rate is expected to result in a surge of capital in‡ows, as the relative return of domestic assets increase. We show that if the government tries to sterilize them, it sets the economy in a path leading to a BOPC. If, on the contrary, the government lets the domestic interest decrease, 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 converge to the international one much faster in countries with currency board arrangements (see Section 2).[27] Second, observe that if the domestic interest rate is kept constant the relative return of domestic bonds increases, and so their demand. This is not what we observe in emerging markets with currency board arrangements. Absent risk, the relative returns of domestic and international bonds should stay the same.[28]

This is the most important result derived in the paper, as we have already emphasized that such a pattern of capital in‡ows and sudden out‡ows 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 2.

[27] 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.

[28] 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 e¤ect in a pure currency board, bond exchanges arise only as a consequence of level e¤ects, and they are not signi…cant.

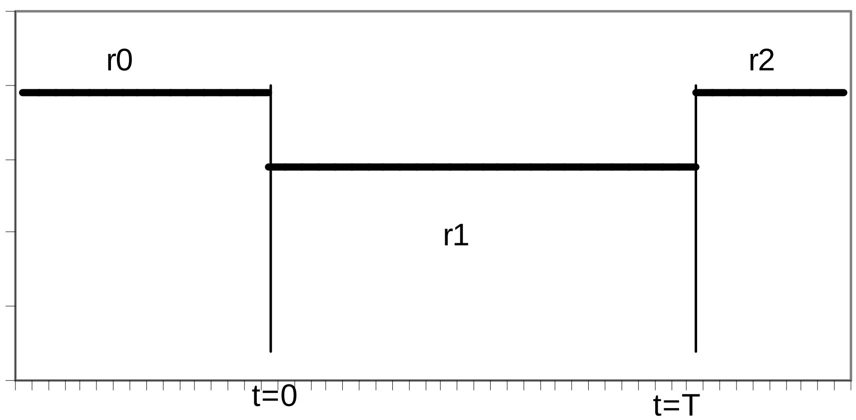
The path of international interest rates is[29]

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

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

where r^h and r^l ($r^h > r^l$) denote the high and low international interest rates, respectively (see Figure 5)

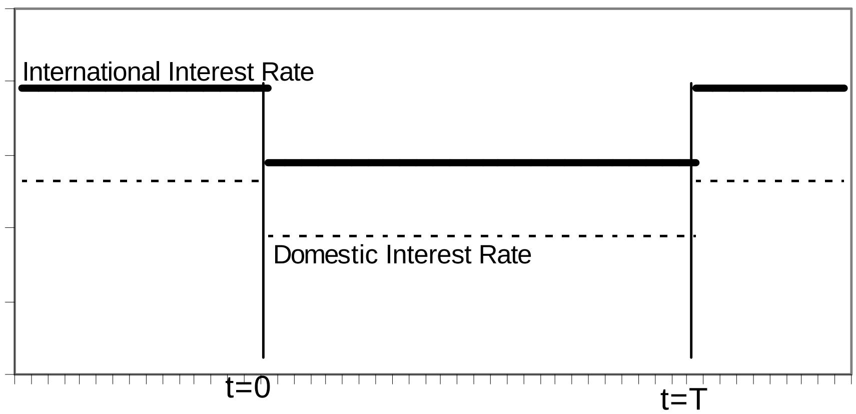
Figure 5. International Interest Rates



It would be more reasonable or 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. In Figures 6 and 7 we can see the time-paths of the interest rate paid on the domestic bond in the case of the pure currency board and in the sterilization case, respectively.

Figure 6. Domestic Interest Rates in the Pure Currency Board

[29] 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).



5.1 Pure Currency Board Case

In the pure currency board case, we can derive a general result.[30]

Proposition 5 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 decrease during the low international interest rates period, and so there will not be a currency crisis afterwards (see Section 4.1.1)

Define x as the percentual 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 will not be substitution effects at t=0. Assume for now that there are no

[30] 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 strenghten capital inflows, but also put the economy in a path leading to a BOPC.

level effects at t=0 also. Then budget balance requires

$$\begin{aligned}
g_0 + \bar{i}_0 d_0 &= r_0 k_0 && \text{(for } t < 0\text{)} \\
g_0 + \bar{i}_0(1 - x)d_0 + \dot{k}_t &= r_0(1 - x)k_0 && \text{(for } t \geq 0\text{)} \\
-\bar{i}_0 x d_0 + \dot{k}_t &= -r_0 k_0 x \\
\dot{k}_t &= -x(r_0 k_0 - \bar{i}_0 d_0)
\end{aligned}$$

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 lower international interest rates. Now we want to argue that there is a positive level effect at time 0. First note that a decrease in the international interest rate induces a positive wealth effect. In addition, we have shown in Section 3.4 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

$$c_t = C \cdot D \cdot \left(q^l\right)^{-\delta} e^{-(r_0 - r_1)\delta t} \tag{33}$$

for $0 \leq t \leq T$, where

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

and

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

After t=T, consumption is equal to

$$c_t = c_T\left(\frac{q^l}{q^h}\right)^{\delta} \tag{34}$$

where C_T is given by (33) evaluated at t=T. From (33) and (34) we can deduce that:

- the MPC increases at t=0, as the denominator decreases more than the numerator. In addition, as f_0 is assumed to be negative, a fall in the international interest rate increases the wealth of the representative agent. 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 (33) at those points,

- consumption falls at t=T, as $q^l < q^h$

- consumption is constant after t=T

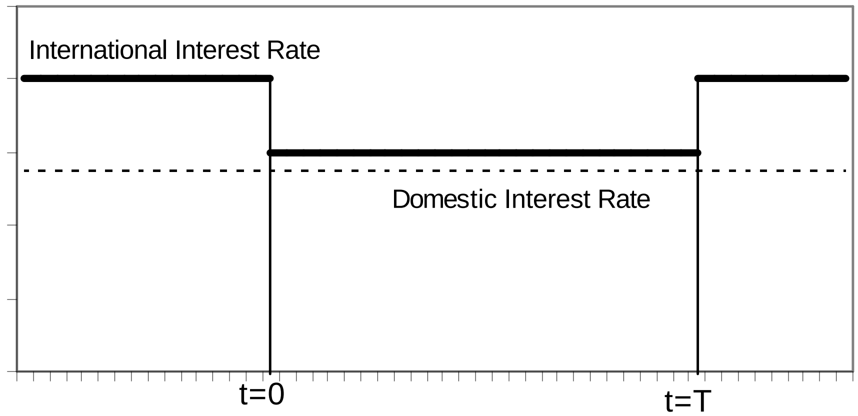
From the …rst of these points we see that there is a positive level e¤ect at t=0. The positive level e¤ect increases m, d, and hence to a greater extent k. This enhances the rate of growth of reserves, although this e¤ect is partially o¤set by the fall in consumption up to t=T. ■

5.2 Sterilization

We model the sterilization case as that in which the Central Bank does not allow the domestic interest rate to be reduced pari-passu with the international one, raising the relative return of the domestic bond and thus its demand. This is likely to deteriorate 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).[31]

Figure 7. Domestic Interest Rates in the Sterilization Case

[31] This is partially o¤set 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 e¤ect on liquid assets demand is positive (see Table 4), the increase in int. reserves is undoubtely lower than the one in domestic bonds outstanding.



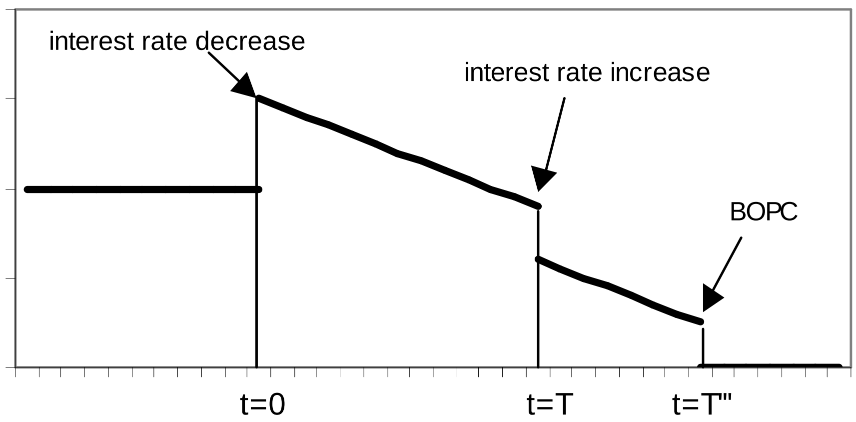
As one can expect, the impact of these changes on the finances of the public sector depends on:

1. The length of the international interest rate decrease, and

2. The magnitude of the international interest rate decrease,

as for a very small decrease and/or a very short period of lower interest rates, the sterilization effects can be insignificant. Note that there are three possible cases, depending on whether the BOPC, if any, 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, and only when the discount rate is constant. In Figure 8 we can see one possible path for international reserves.

Figure 8. International Reserves Path (Sterilization Case)



In the sterilization case we have 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.

To show this result, we follow the same steps as in Section 4.1.

First we have to show that if k=0 after some time (i.e.: after t=T), $\varepsilon_2 > 0$: Budget balance after t=T requires in this case that:

$$(ª\ ´\ )\varepsilon_2(m_2 + d_2) - g_0 - i_0 d_2 = 0 \tag{35}$$

Note that dividing both sides by d_2 we do not get a function of ε solely (for r and i constant) as before. As for positiveness, note that

$$ª(0; c) = -g_0 - i_0 d_2 < 0$$

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

$$\begin{aligned} ª(\varepsilon_2 &= i_0; c) = i_0(m_2 + d_2) - g_o - i_0 d_2 \\ &= i_0 m_2 - g_o > 0 \end{aligned}$$

To prove monotonicity, divide both sides of equation (35) by d_2;

$$\varepsilon_2 \left(\frac{m_2}{d_2} + 1 \right) - g_o \left(\frac{1}{d_2} \right) - i_0 = 0$$

and de…ne £ = $\frac{m_2}{d_2}$ and ¨ = $\frac{1}{d_2}$.We know that: $\frac{@£}{@"_t}\Big|_{r;i}$ > 0 and $\frac{@¨}{@"_t}\Big|_{r;i}$ > 0 (see equation (8) and Table 4). Then $g_2 < 0$ implies that a unique (positive) $"_2$ satis…es condition (35).

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 e¤ect and a level e¤ect at time t=0. If there is a BOPC at some point in the future, there would be an additional level e¤ect at t=0. Following the logic of Section 4, we only need to prove that the substitution e¤ect and the initial level e¤ect would leave the public sector …nances unbalanced, leading to a loss of reserves.

The additional level e¤ect would bring a positive e¤ect on the demand of domestic assets at time 0, unambiguously increasing the stock of domestic bonds. If the additional level e¤ect made the situation sustainable then $"_2 = 0$ and there would be no BOPC. But this is a contradiction, since the additional level e¤ect is conditional on the BOPC taking place:

So we need to show that the initial substitution and level e¤ects leave the public sector unbalanced[32]. Budget balance requires

$$\begin{aligned} g_0 + \overline{i_0}d_0 &= r_0k_0 && \text{(for t<0)} \\ g_0 + \overline{i_0}(d_0 + ¢d_0^{ilev} + ¢d_0^{sub}) + \overset{²}{k}_t &= r_0(1 ¡ x)(k_0 + ¢k_0^{ilev} + ¢k_0^{sub}) && \text{(for t ¸ 0)} \\ g_0 + \overline{i_0}d_0 + \overline{i_0}¢d_0 + \overset{²}{k}_t &= r_0k_0 + r_0¢k_0 ¡ r_0x(k_0 + ¢k_0) \\ \overset{²}{k}_t &= r_0¢k_0(1 ¡ x) ¡ r_0xk_0 ¡ \overline{i_0}¢d_0 && (36) \end{aligned}$$

So $\overset{²}{k}_t < 0$ from t = 0 to t = T i¤

$$\begin{aligned} r_0¢k_0(1 ¡ x) ¡ r_0xk_0 ¡ \overline{i_0}¢d_0 &< 0 \\ ¡ r_0x(¢k_0 + k_0) &< \overline{i_0}¢d_0 ¡ r_0¢k_0 \\ x &> \frac{(r_0¢k_0 ¡ \overline{i_0}¢d_0)}{r_0(¢k_0 + k_0)} && (37) \end{aligned}$$

To calculate the values of $¢k_0$, $¢d_0$; 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

[32] It would be su¢cient to show that public …nances are unbalanced after t=T.

the international interest rate, and so the representative household will have a decreasing consumption path.

We can calculate that

$$k_T = [k_0 + \Delta k_0]e^{r_1T} - g_0\left(\frac{e^{r_1T} - 1}{r_1}\right) - Fe^{r_1T}\int_0^T c_t e^{-r_1t}dt \tag{38}$$

where c_t is given by equation (33), and

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

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

$$\int_0^T c_1^* e^{-r_1t}dt = \int_0^T c_t e^{-r_1t}dt$$

It can be shown that c_1^* is given by

$$c_1^* = C * D * E * \left(q\right)^{-\delta} \tag{39}$$

where C and D are as before, and

$$E = \left(\frac{1 - e^{-(r_1(1-\delta)+\delta r_0)T}}{r_1(1-\delta) + \delta r_0}\right)\left(\frac{r_1}{1 - e^{-r_1T}}\right)$$

After t=T, public sector balance requires

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

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

$$r_0(k_T - \Delta k_T) - g_0 - \bar{i}_0(d_T - \Delta d_T) < 0 \tag{40}$$

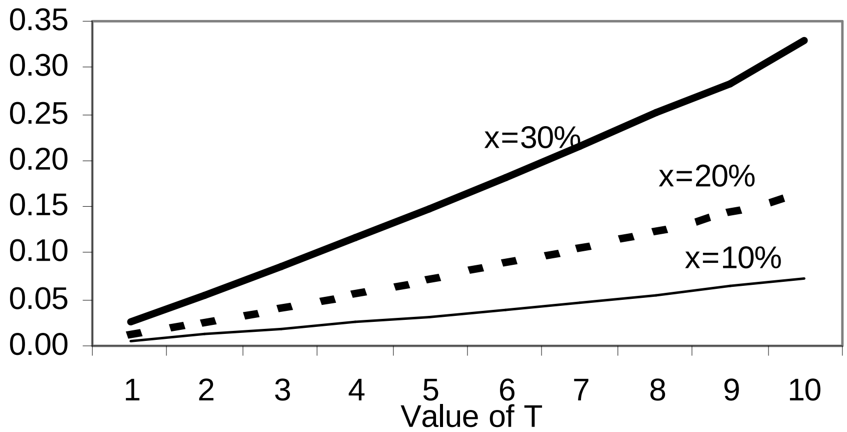
where k_T is given by equation (38). We cannot derive analytically explicit thresholds (combinations of T and x in this case) above which the economy will have a BOPC at some (finite) point in the future. That is, we cannot check analytically whether (37) and (40) are simultaneously satisfied and so reserves will be falling not only from $t = 0$ to $t = T$, but also after $t = T$:

Numerical simulations using the same assumptions of Appendix D show that any combination of x and T would lead the economy to a BOPC if the government tries to sterilize. 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 fiscal adjustment would be needed at $t = T$ to restore fiscal balance without losing reserves from then on (avoiding a future BOPC).

In Figure 9 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 10 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.

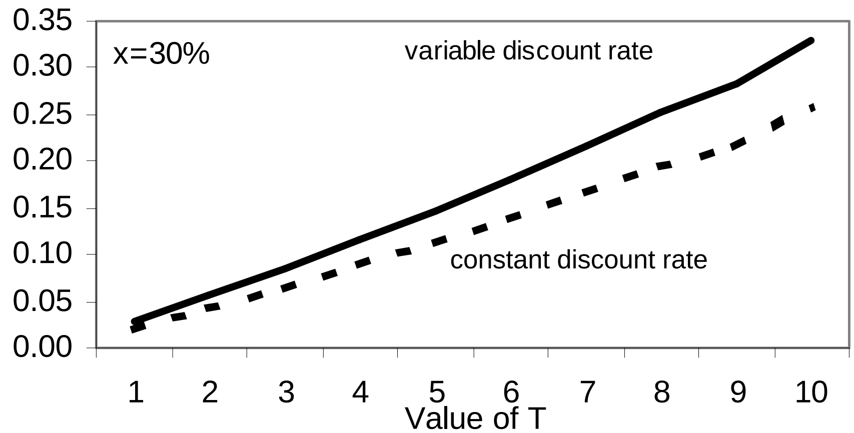
Figure 9. Required Fiscal Adjustment at t=T (as % of GDP) to Restore Balance



It may seem that long years of low international interest rates are requiered to generate a sizable …scal disequilibrium when the central bank sterilizes capital in‡ows. But that is not the case in the context of the model. To have some reference value for comparison, recall from Section 4 (Table 6) that if the government eliminated the primary surplus at $t = 0$ (assuming that the international interest rate remains constant), it would take from $T = 7$ to $T = 17$ years to have a BOPC. The high values of T are probably a result of the assumption that the government earns a higher interest rate for its reserves than what it pays for its debt. Moreover, the lower bound on k has been set to zero in all cases (see equation (15)), a simplifying but unrealistic assumption.

In Figure 10, that has the same interpretation as Figure 9, we can compare the results of a reduction of 30 percent in the international interest rate in the constant (dotted line) and the changing (solid line) discount rate cases.

Figure 10. Required Fiscal Adjustment at $t=T$ (as % of GDP) to Restore Balance



Note that the harmful fiscal effects of sterilization are reduced in the case of a constant discount rate. This is because a constant discount rate not only tilts consumption during the low international interest rates period, but also increases it. That is, c_1^* (given by (39)) is higher than the c_1 from the variable discount rates case. The level effect is bigger and so is the increase of reserves at $t=0$, reducing the fiscal deficit.

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 8. But this contradicts the fact that countries that sterilize usually increase their International Reserves during periods of low international interest rates (see Figure 1 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.[33]

5.3 Discussion

We have argued in this section that an attempt by the government 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.

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

It is important to notice that in our model the government sterilizes twice. It …rst sterilizes capital in‡ows by not letting the domestic interest rate to decrease along with the international one. But it also sterilizes capital out‡ows after the international interest rate increases again, by keeping the domestic interest rate constant.[34]

The mechanics are the following. The sterilization of capital in‡ows increases the domestic debt in the period of low international interest rates, and the …scal de…cit created in this way reduces international reserves. When international interest rates rise, the sterilization of capital out‡ows 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 in‡ows from 1992 to February of 1994, when it started to sterilize capital out‡ows. The reason why we call 1992-93 a period of temporary low international interest rates is clear from Figure 2. We leave other cases for future research.

6 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 in‡ows compared to the 80's, and the repeated balance of payments crises (BOPC) associated with the sudden reversals of these ‡ows.

Empirical …ndings point out that external factors continue to be highly relevant to the determination of the "timing and magnitude" of capital ‡ows to developing countries. Policymakers have usually tried to avoid the expansionary e¤ects of capital in‡ows, and sterilization

[34] The sterilization of capital out‡ows is behind the results derived by Kumhof (1998). Lahiri and Vegh (1999), on the contrary, study the e¤ects of …ghting capital out‡ows with increased domestic interest rates.

has been the most widespread type of intervention.

This is the …rst paper to model in a general equilibrium framework the relationship between the sterilization of capital in‡ows and balance of payments crises. Many objections can be placed on sterilization, amongst them that it deteriorates the …nances of the public sector. We have exploited this fact to argue that, under di¤erent assumptions concerning the consistency of the monetary/…scal policy with the exchange rate peg, sterilization is never the best policy response to capital in‡ows. 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 ine¤ective in the sense that it does not reduce the current account de…cit.

Our results suggest that an attempt to sterilize the capital in‡ows 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-…nancial public sector de…cit 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 in‡ows with short-term bonds, and later sterilized capital out‡ows 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 de…cits 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 di¤erent context, this may give additional interesting dynamics to the model.

Appendix A

We want to show that

$$\left.\frac{\partial I_t}{dc_t}\right|_{r,i,\varepsilon} > 0 \text{ and } \left.\frac{\partial I_t}{dX_t}\right|_{c} < 0$$

From equations (12) and (10),

$$\left.\frac{\partial I_t}{\partial c_t}\right|_{r,i,\varepsilon} = \frac{\alpha(W\psi(X_t)+1).}{L(W\psi(X_t),1)} > 0$$

and (we eliminate the arguments when there is no source of confusion),

$$\begin{aligned}\left.\frac{\partial I_t}{\partial X_t}\right|_{c} &= \frac{\alpha C_t}{L^2}\left\{\psi'(X_t)WL - (1+\psi(X_t)W)\frac{\partial L}{\partial \psi(X_t)}\psi'(X_t)\right\} \\ &= \frac{\alpha C_t}{L^2}\psi'(X_t)W\{L - L_m - L_m\psi(X_t)\} \\ &< 0\end{aligned}$$

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

Appendix B

We want to show that the timing of the BOPC is brought forward if the government attempts to sterilize capital inflows at $t=0$. First rewrite equation (31) as:

$$e^{rT} = \frac{\beta\alpha c_1 - \alpha c_2 rSL(W\psi_1,1)}{\beta\alpha c_1 - rk_0L(W\psi_1,1)} \tag{A1}$$

We want to show that the combined effects of a permanent increase in the interest rate and the higher devaluation rate after the BOPC (ε_2) bring forward the timing of the BOPC. We show it in steps. First, we need to prove that

$$\left.\frac{\partial e^{rT}}{\partial i_t}\right|_{r,\varepsilon} < 0 \tag{A2}$$

which will hold if and only if:

$$D\left\{\alpha c_1 + \alpha\bar{\beta}\frac{\partial c_1}{\partial i} - \alpha r S L\frac{\partial c_2}{\partial i} - \alpha c_2 r L\frac{\partial c_2}{\partial i} - \alpha c_2 r S\frac{\partial L}{\partial i}\right\} - N\left\{\alpha c_1 + \alpha\bar{\beta}\frac{\partial c_1}{\partial i} - r k_0\frac{\partial L}{\partial i}\right\} < 0$$

where D and N stand for the denominator and numerator of equation (A1), respectively. We know that a permanent change in the interest rate brings no level effect unless it induces a subsequent increase in ε_2. Then

$$\left.\frac{\partial c_j}{\partial i_t}\right|_{r,\varepsilon_1,\varepsilon_2} = 0 \text{ for } j = 1, 2$$

This result mirrors the one derived in Calvo and Vegh (1990). We also know that

$$\left.\frac{\partial L(W\pi_1, 1)}{\partial i_t}\right|_{r,\varepsilon} < 0$$

and that

$$S = \left(\frac{W\pi_1 + 1.}{L(W\pi_1, 1)} - \frac{W\pi_2 + 1.}{L(W\pi_2, 1)}\right) > 0$$

as the overall substitution effect must be negative for an increase in ε (see Table 4), and we have defined S as the negative of the substitution effect. In addition,

$$(D - N) * [\alpha c_1] < 0$$

since D-N<0. So to prove (A2) it would be sufficient to show that

$$D\left\{-\alpha c_2 r L(W\pi_1, 1)\frac{\partial S}{\partial i} - \alpha c_2 r S\frac{\partial L}{\partial i}\right\} - N\left\{-r k_0\frac{\partial L}{\partial i}\right\} \leq 0$$

$$D\left\{\alpha c_2 r L(W\pi_1, 1)\frac{\partial S}{\partial i} + \alpha c_2 r S\frac{\partial L}{\partial i}\right\} \geq N\left\{r k_0\frac{\partial L}{\partial i}\right\}$$

$$\alpha D\left\{c_2 L(W\pi_1, 1)\frac{\partial S}{\partial i} + c_2 S\frac{\partial L}{\partial i}\right\} \geq N\left\{k_0\frac{\partial L}{\partial i}\right\}$$

$$\alpha D c_2 L\frac{\partial S}{\partial i} \geq \{N k_0 - \alpha D C_2 S\}\frac{\partial L}{\partial i}$$

Note that we can expect $\left.\frac{\partial S}{\partial i_t}\right|_{r;\varepsilon}$ t 0, as a change in i affects both terms in the same direction and similar magnitude. So it would be sufficient to have $\{N k_0 - \alpha D c_2 S\} \geq 0$; for what, given that N>D, it would be sufficient to have $k_0 \geq \alpha c_2 S$. This is the case, since $\alpha c_2 S = \Delta k_T^{sub}$:

From equation (25), we can calculate that the increase in ε_2 needed to restore fiscal balance after the speculative attack is given by

$$\frac{d\varepsilon_2}{di} = \frac{[1 + \varepsilon_2 W X^{\sigma}(\frac{1}{l-i})]}{[1 + W X^{\sigma} + \varepsilon_2 i \sigma W X^{\sigma}(\frac{1}{l-i})]} = N$$

where $0 < N < 1$. So it would be sufficient to have $\frac{\partial e^{rT}}{\partial \varepsilon_2}$ positive but of lower magnitude than $\frac{\partial e^{rT}}{\partial i_t}$: But in fact it can be shown that

$$\left.\frac{\partial e^{rT}}{\partial \varepsilon_2}\right|_{r;i;\varepsilon_1} < 0$$

After some algebra, it is possible to show that

$$\frac{-\frac{\partial C_2}{\partial \varepsilon_2}}{C_2} \leq \frac{\frac{\partial S}{\partial \varepsilon_2}}{S}$$

is a sufficient condition for this. This inequality holds, as both numerators are of similar absolute value, while the denominator in the LHS is higher than the one in the RHS. This concludes the proof.

Appendix C

We want to show that, starting from a steady state position, any permanent increase in the domestic interest rate deteriorates the fiscal position (all else equal). Although international reserves initially increase, the fiscal deficit leads to a BOPC in finite time.

Define $\delta_t = g_t + i_t d_t - r k_t$ as the fiscal deficit at time t. For given levels of c, r and ε; δ_t is a function of i only. We want to show that

$$\frac{\partial \delta_t(i_t)}{\partial i_t} > 0 \qquad \text{(A3)}$$

Condition (A3) holds iff

$$d_t - r\frac{\partial m_t}{\partial i_t} > \frac{\partial d_t}{\partial i_t}(r - i) \tag{A4}$$

As the second term on the LHS and the RHS of (A4) are strictly positive, it is sufficient to show that

$$
\begin{aligned}
& d_t \geq \frac{\partial d_t}{\partial i_t}(r - i) \\
\Leftrightarrow\ & d_t \geq d_t \frac{\omega\left(\frac{m_t}{d_t}\right)^{\frac{\sigma-1}{\sigma}} \sigma \frac{1}{r-i}}{\omega\left(\frac{m_t}{d_t}\right)^{\frac{\sigma-1}{\sigma}} + (1-\omega)}(r - i) \\
\Leftrightarrow\ & \omega\left(\frac{m_t}{d_t}\right)^{\frac{\sigma-1}{\sigma}} \sigma \leq \omega\left(\frac{m_t}{d_t}\right)^{\frac{\sigma-1}{\sigma}} + (1-\omega) \\
\Leftrightarrow\ & \omega\left(\frac{m_t}{d_t}\right)^{\frac{\sigma-1}{\sigma}} (\sigma - 1) \leq (1-\omega)
\end{aligned}
$$

which holds for $\sigma \leq 1$.

Appendix D

Calibration

The values of parameters σ and δ are taken from Kumhof (1998), which estimated them using Mexican data. The other parameters were chosen to match certain key variables of emerging economies. They are

σ	δ	A	α	ω
0.74	0.10	1	0.3	0.4

We normalized the (constant) endowment per period to 100, so that all the other variables can be interpreted as percentages of GDP. The international interest rate is set equal to the average short term interest rate in the US. For the other variables we have assumed the following initial values,

y	b_0	r_0	i_0	k_0
100	-50	6%	4%	14

These values are consistent with the evidence from emerging Latin-American and Asian economies of international reserves of approximately 14 percent of GDP and gross external debt of 45 percent of GDP. From equations (20), (9), (12), and (16) we can calculate the initial values of c_0, d_0, m_0 and g_0, respectively. These are

c_0	d_0	m_0	g_0
97.8	48.3	18.9	-1.1

The values of domestic debt/GDP (48.3%) and of money/GDP (18.9%) also seem in line with the data. The notable exception is the assumption about domestic interest rates, which in our model su¤ers from the anomaly explained in Section 3.

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