Exchange Rate Based Stabilization Under Capital Account Restrictions*

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Abstract

This paper studies an Exchange Rate Based Stabilization (ERBS) plan when the economy is subject to capital account restrictions. We present a simple theoretical model which mimics the stylized facts associated with recent ERBS plans. In particular, the model is able to explain reserve losses and real interest rate movements before the end of these plans, as observed in the data. Interestingly, the analysis suggests that consumption boom-bust cycles during ERBS plans may be amplified in the presence of capital account restrictions. Finally, we find that capital account restrictions may be triggered even when the debt ceiling is higher than the debt level that accumulates under perfect capital mobility. Hence, anticipated capital restrictions may lead to 'overborrowing' relative to the case when capital is perfectly mobile. Our empirical analysis supports our theoretical conclusions.

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1 Introduction

A voluminous literature has addressed the empirical regularities associated with Exchange Rate Based Stabilization (ERBS) plans.[1] These plans, particularly the more recent ones, have been generally associated with the following stylized facts. First, the plans are eventually abandoned, followed by exchange rate collapse and rise in inflation. Second, there is a consumption boom when the plan is in place, followed by a sharp decline once the plan collapses. Third, the current account deficit widens while the plan is being implemented. Fourth, the stock of foreign reserves gradually and persistently declines towards the end of the plan. Finally, real interest rates rise towards the end of the plan and then decline when the plan is over.

While the literature has mainly focused on explaining the boom-bust cycle and the associated real exchange rate dynamics, reserve movements and real interest rate movements have been largely ignored. Figure 1 documents the movements of foreign exchange reserves, real interest rates, and current accounts for selected economies that underwent ERBS plans towards the end of the plan. All four episodes depicted in Figure 1 illustrate cases of chronic current account deficits accompanied by foreign exchange reserve losses prior to the collapse of the plan. Additionally, we observe that significant losses in the reserves began up to four quarters prior to the collapse.[2] Finally, the falling reserves are accompanied by high real interest rates just before the end of the plan. A rise in real interest rates towards the end of the plan has also been documented by Calvo and Végh (1993) in their study of ERBS episodes. However, the literature has failed to offer a theoretical model that explains reserve losses and rise in real interest rates prior to the collapse of ERBS plans[3]. This paper attempts to address this gap. In addition, the paper examines the consequences of capital account restrictions on consumption boom-bust cycle.

The existing literature on ERBS plans have almost always made the assumption of perfect capital mobility in their models. Given the fact that emerging markets routinely lose their access to international capital markets,

[1]See Calvo and Végh (1999) for an excellent survey on ERBS plans.

[2]Two quarters for Brazil, three quarters for Mexico, four quarters for Argentina and two quarters for Malaysia.

[3]Lahiri (2001), for example, is able to capture the decline in reserves prior to the collapse of the program, but is unable to account for the real interest rate movements.

we feel that this is an unrealistic assumption. ERBS episodes have frequently been characterized by large capital inflows and current account deficits, followed by a reversal or a slow down of capital flows and subsequent current account adjustments. Given this evidence, it only seems natural to study ERBS plans under the presence of capital account restrictions.

We show that capital account restrictions along with temporariness of ERBS plans better explain the stylized facts. The temporariness hypothesis was popularized by Calvo (1986). In a seminal paper, he argued that the boom-bust cycles associated with these plans results from the lack of credibility in government policies. The credibility problem via intertemporal substitution rationalizes the observed business cycles. However, the framework, which assumes perfect capital mobility, is unable to account for the reserve and real interest rate movements. The introduction of capital account restrictions in the temporary stabilization plan framework not only helps us explain real interest rate and reserve movements, but also helps us examine the consequences of capital account restrictions on consumption patterns.

We find that anticipated restrictions on capital flows can potentially result in amplification of the boom-bust cycle relative to the case where there are no restrictions on capital flows. Moreover, even when the debt ceiling at which the restrictions are anticipated to bind is higher than the debt accumulated under perfect capital mobility, the anticipation of restrictions can be self-fulfilling, resulting in episodes of 'overborrowing'.

The central idea behind our explanation is the following. An ERBS plan is implemented at time 0, which is expected to last until time T^*. At the same time, households anticipate that they will be cut off from international capital markets when the private foreign debt level reaches a commonly known value $\hat{b}$.[4] The intertemporal inflation differential caused by the temporary ERBS plan induces households to tilt consumption to a higher level while the plan is in place and inflation is low. The resulting trade deficit is financed by external borrowings. At some point of time $\hat{T} < T^*$, when the private debt level reaches $\hat{b}$, the households are cut off from capital markets. Since the inflation is still lower than that anticipated in the future, households prefer to maintain a higher level of consumption. However, now they cannot

[4]This assumption provides us with the flexibility to study the implications of restrictions on capital inflows as well as outflows. As is discussed later in the text a low value of $\hat{b}$ would imply that the restrictions exist mainly on capital inflows. A high value of $\hat{b}$ on the other hand would imply the restrictions fall on capital outflows.

borrow anymore. Neither can they rebalance their asset portfolio between real balances and bonds that allows them to adjust consumption quickly to a lower level, when the plan collapses. As a result, the consumption adjusts gradually. Initially, the country keeps running current account deficits that are now financed by running down foreign reserves instead of by foreign borrowings. Hence, foreign reserves deplete gradually. Further, since the households cannot consume as much as they would like to while the inflation is low, the real interest rate rises. On the other hand, the gradual adjustment of consumption implies that for some time households consume more than their permanent income even after the plan collapses. As a result, the real interest rate declines in the post-collapse period.

Interestingly, we find that the consumption boom-bust cycle is crucially affected by the international debt ceiling. If the ceiling is sufficiently low, the restrictions essentially constrain *inflows.* Consequently, real interest rate is high while ERBS is going on, which induces agents to forego consumption. As a result, boom-bust cycle is subdued.[5] On the other hand, if the debt ceiling is sufficiently high, anticipated restrictions on capital flows can further amplify boom-bust cycles. To see this, suppose $\hat{b}$ is infinitesimally smaller than the level of private debt that the economy will accumulate by the end of the ERBS plan in a world of free capital mobility. It is easy to see that atomistic household behavior will cause the private debt level reach $\hat{b}$ eventually, before the end of the stabilization plan. In a world of perfect capital mobility, agents would like to switch to a lower consumption once the inflation returns to a high level. Given predetermined exchange rates, this would be achieved by agents exchanging money for bonds at the central bank. In our model, given that we have capital account restrictions, agents cannot rebalance their portfolio and hence cannot reduce their consumption instantaneously in response to higher inflation rates. In this scenario, therefore, the restrictions constrain *outflows.* As a result, real interest rates are low after the ERBS collapse, which induces agents to continue with a high level of consumption relative to the perfect capital mobility world. Thus, the consumption boom is prolonged. Furthermore, in order to continue with high consumption after the restrictions are imposed, agents accumulate higher real balances while

[5]This is consistent with Calvo (1986) who advocated that in an environment of imperfect credibility the use of capital controls might be welfare enhancing as it may ameliorate the boom-bust cycle.

the ERBS is on. This in turn, boosts the consumption further up during the low inflation period. Overall, the boom-bust cycle is amplified. Thus, in general, whether capital restrictions improve welfare relative to the perfect capital mobility world depends on whether the debt ceiling is below or above a threshold value.

A striking result of our model is that even when the debt ceiling is high enough such that it would not have been reached under perfect capital mobility, anticipated restrictions can now be self-fulfilling. Observe that under perfect capital mobility, the path of real interest rate always equals the world interest rate. Under restrictions, if the debt ceiling is sufficiently high, the path of real interest rate on average is below the world interest rate. Hence, an anticipated capital restrictions lead to 'overborrowing' relative to the case when capital is perfectly mobile.

To empirically test the validity of our theoretical model, we focus on the pattern of persistent reserve losses and real interest rate movements during ERBS plans. We investigate the probability of significant and persistent reserve losses and rise in interest rates prior to the collapse of stabilization plans based on probit model regressions against a pooled time-series quarterly data set of 33 developing economies from 1975 to 2001 and against a data set of ERBS episodes identified in Easterly (1996), Hamann (2001), and Calvo and Végh (1999). The results of the empirical section clearly suggest that chronic current account deficits coupled with a stop in short-term capital inflows could account for the dynamics of reserve losses and real interest rate during these stabilization plans.

Our work is closely related to two papers in the literature. In a study of Mexican stabilization between 1987-1994, Atkeson and Rios-Rull (1996) suggest that a slowdown in capital flows coupled with large current account deficits could account for the reserve losses prior to the collapse of the plan. In their framework, however, the collapse of the plan is accompanied by an increase in output levels. This is clearly counterfactual. Kumhof (2000) in another study attributes the sustained reserve losses in Mexico in the year 1994 to portfolio reallocation from domestic to foreign bonds. Our paper with its focus on current account deficits as a cause for reserve losses could be interpreted as a competing explanation to Kumhof's hypothesis.[6]

The rest of the paper is organized as follows. In Section 2 we present our

[6] We thank an anonymous referee for pointing this out.

basic model. Section 3 first sets up a benchmark model undergoing a temporary ERBS plan and then studies the dynamics under perfectly anticipated restrictions on capital flows. Section 4 establishes a range of debt ceilings that are consistent with anticipated restrictions and examines their impact on consumption boom-bust cycles. Section 5 extends the analysis to the case when the restrictions on capital flows are unanticipated. Section 6 presents empirical evidence and Section 7 concludes.

2 The Model

Consider a small open economy inhabited by a large number of identical households blessed with perfect foresight. There is one consumption good, which can be perfectly traded in world markets at a fixed world price of unity. Hence, the home price of consumption good is equal to the nominal exchange rate, E, expressed in units of home currency per unit of world currency. In addition, there is an international bond market where all transactions take place in terms of consumption good at a fixed world interest rate r.

2.1 Households

The representative household's lifetime utility is given by

$$\int_0^\infty u(c_t)\exp(-\beta t)dt; \quad u' > 0,\ u'' < 0, \tag{1}$$

where $\beta \geq 0$ is the rate of time preference, and c_t is the amount of consumption. To avoid trends in variables, we assume $\beta = r$. The domestic real interest rate ρ_t, however, may differ from the world real interest rate, r, due to imperfect capital mobility. The household's wealth in terms of consumption good is given by

$$a_t = m_t - q_t b_t,$$

where a_t denotes net financial assets, $m_t \equiv M_t/E_t$ is the amount of real balances while M_t denotes nominal balances, and b_t denotes the stock of international debt. Hence, $b_t > 0$ (< 0) implies that the household is a net debtor (creditor) in the international bond market. q_t denotes the price of international bonds in terms of consumption good. The domestic real interest rate is $\rho_t = (r + \dot{q}_t)/q_t$ and under perfect capital mobility, $q_t \equiv 1$ and $\rho_t = \beta$.[7] Under capital account restrictions, we will assume that the stock of foreign assets with the public remains constant over time and then, in general, $q_t \neq 1$.

The household receives a constant flow y of the consumption good. The flow constraint of the household in terms of the tradable good is given by

$$\dot{a}_t = \rho_t a_t + y - c_t - i_t m_t + \tau_t, \tag{2}$$

where i_t is the nominal interest rate. Note that $i_t = \rho_t + \epsilon_t$, where $\epsilon_t \equiv \dot{E}_t / E_t$ is the rate of devaluation of nominal exchange rate. The term $i_t m_t$ reflects the opportunity cost of holding money, and τ_t denotes lump sum transfers from the government.

Households must use money to purchase goods. Formally, they face a cash-in-advance constraint of the form

$$\alpha c_t \leq m_t, \tag{3}$$

where α is a positive constant. Equation (3) requires that the stock of real money balances should not fall short of consumption expenditure c_t. Since the nominal interest rate is positive in equilibrium, we assume that the constraint (3) always holds with equality. Then, the household's flow budget constraint can be rewritten as

$$\dot{a}_t = \rho_t a_t + y - c_t \left(1 + \alpha i_t\right) + \tau_t, \tag{4}$$

At time 0, let the household's debt and real balances be $\bar{b}$ and $\bar{m}$, respectively. Then, given the expected paths of y, τ_t, ρ_t, and i_t,the household's optimization problem consists of choosing the path of c_t that maximizes lifetime utility, (1), subject to its flow constraint, (4). The first order conditions are

$$u'(c_t) = \lambda_t (1 + \alpha i_t) \tag{5}$$

[7] Following Guidotti and Végh (1992), we assume that there exists a dual exchange rate system whereby all *commercial* transactions including interest rate payments take place at a fixed commercial rate E, while *financial* transactions are channeled through the freely floating financial exchange rate Q. Note that q equals the ratio of the financial exchange rate Q and the commercial exchange rate E, i.e., $q = Q/E$.

and

$$\dot{\lambda}_t = \lambda_t \left(\beta - \rho_t\right), \tag{6}$$

where λ_t is the costate variable. Equation (5) states that the marginal utility of consumption equals its price as represented by the shadow price of wealth. The term $1 + \alpha i_t$ reflects that the effective price of consumption includes the opportunity cost of holding real money balances needed to purchase goods. Equation (6) describes the law of motion of costate variable in the standard way. Note that under perfect capital mobility, $\rho_t = r = \beta$, and $\dot{\lambda}_t = 0$ for all t.

2.2 Government

The government includes the central bank. The flow constraint of the government is given by

$$\dot{h}_t = rh_t + \dot{m}_t + \epsilon_t m_t - \tau_t, \tag{7}$$

where h_t is the government's stock of net foreign assets and τ_t is the lump sum transfer to households. Note that the term $\dot{m}_t + \epsilon_t m_t$ represent the proceeds from money creation. The government has two instruments through which it can control monetary policy. It can set the future path of exchange rates and/or the path of domestic credit. The government sets the rate of domestic credit as

$$\frac{\dot{D}}{D_t} = \mu_t,$$

where D_t is the level of domestic credit and μ_t is the rate of growth of domestic credit. The domestic credit rule implies a specific transfer policy. To see this, first notice from the central bank's balance sheet that

$$E_t h_t + D_t = M_t.$$

Using the domestic credit rule and the central bank's balance sheet identity in (7) yields the transfer policy

$$\tau_t = \epsilon_t h_t + \mu_t d_t + rh_t, \tag{8}$$

where $d_t = D_t/E_t$. Substituting (8) in (7) yields

$$\dot{h}_t = \dot{m}_t - d_t \left(\mu_t - \epsilon_t\right). \tag{9}$$

Note that (9) implies that for a constant money demand, i.e., $\dot{m}_t = 0$, setting $\mu_t \neq \epsilon_t$ would result in a continuous loss or accumulation of international reserves. To avoid such scenarios, we assume $\mu_t = \epsilon_t$, which implies that the government keeps its domestic credit fixed in real terms. Therefore, the central bank's balance sheet identity can be rewritten as

$$m_t = h_t + \bar{d}, \tag{10}$$

where $\bar{d}$ is the constant real level of domestic credit for all t. Further, note from (10) and (8) that

$$\begin{aligned} \dot{h}_t &= \dot{m}_t, \\ \tau_t &= rh_t + \epsilon_t m_t. \end{aligned} \tag{11}$$

The first equation in (11) states that the central bank accumulates foreign reserve only when households accumulate real balances. The second equation implies that inflation revenues and interest earnings on foreign reserves are rebated to the households in a lump sum manner.

2.3 Equilibrium

Combining the household's flow constraint, (2), with the government's flow constraint, (7), yields

$$\dot{h}_t - q_t \dot{b}_t = r(h_t - b_t) + y - c_t. \tag{12}$$

Note that under perfect capital mobility $q_t \equiv 1$, while under capital controls $\dot{b}_t = 0$. In either case, we can rewrite the (12) as

$$\dot{k}_t = rk_t + y - c_t, \tag{13}$$

where $k_t = h_t - b_t$. (13) describes the current account for the economy. Integrating (13) and imposing the transversality condition, $\lim_{t\to\infty} k_t e^{-rt} = 0$, yields the economy's resource constraint as

$$\bar{k} + \int_0^\infty (y_t - c_t)\exp(-rt) = 0 \tag{14}$$

where $\bar{k} = \bar{h} - \bar{b}$, and where $\bar{h}$ is the net stock of foreign reserves at time 0.

2.3.1 Stationary equilibrium under perfect capital mobility

Under perfect capital mobility, the domestic real interest rate equals the world real interest rate, i.e., $\rho_t = r$. Furthermore, under perfect capital mobility the interest rate parity condition implies

$$i_t = r + \epsilon_t. \tag{15}$$

Then the first-order conditions (5) and (6) can be combined to yield

$$u'(c_t) = \lambda(1 + \alpha i_t), \tag{16}$$

where λ now denotes the constant value of the costate variable. Suppose that the rate of devaluation is expected to stay constant forever. Formally, let $\epsilon_t = \epsilon^H$ and, hence, $i_t = r + \epsilon^H$, for all t. Then, it follows from (16) that consumption will be constant. Integrating the resource constraint, (14), yields

$$c_t = \bar{c} = r\bar{k} + y. \tag{17}$$

Equation (17) states that in a world with perfect foresight and no intertemporal distortions, the household chooses a constant level of consumption that equals its permanent income, given that the market rate of interest equals its subjective discount rate. Further, as the cash-in-advance constraint, (3), binds with equality, the stationary level of real balances are

$$\bar{m} = \alpha\bar{c}.$$

Finally, from the central bank's balance sheet, $\bar{h} = \bar{m} - \bar{d}$. Substituting these in (17) yields $\bar{c} = \frac{y - r\left(\bar{b} + \bar{d}\right)}{1 - r\alpha}$.

3 Temporary stabilization with anticipated capital account restrictions

In this section, we first study a temporary ERBS plan under perfect capital mobility, as our benchmark. Following Calvo (1986), we focus on the simple case in which the rate of devaluation is temporarily set at a lower level and is later raised back to its original level. Then, we characterize the equilibrium when the economy anticipates capital accounts restrictions, before the end of the ERBS plan.

3.1 Benchmark case: perfect capital mobility

Suppose at time 0, the economy is in a steady state as described in Section 2.3.1 with a rate of devaluation expected to remain at ϵ^H forever. At time 0, households expect the following policy to be implemented in the future:[8]

$$\epsilon_t = \begin{cases} \epsilon^L, & t \in [0, T^*) \\ \epsilon^H, & t \in [T^*, \infty) \end{cases} \; ; \; \epsilon^L < \epsilon^H. \tag{18}$$

Then from (15) the path of nominal interest rate is given by

$$i_t = \begin{cases} i^L = r + \epsilon^L, & t \in [0, T^*) \\ i^H = r + \epsilon^H, & t \in [T^*, \infty) \end{cases} \; ; \; i^L < i^H. \tag{19}$$

Equation (16) then implies that the effective price of consumption is lower during $t \in [0, T^*)$. Therefore it follows from (14) and (16) that consumption during $t \in [0, T^*)$, denoted as c_1^*, will be constant but greater than the constant level of consumption during $t \in [T^*, \infty)$, denoted as c_2^*. Further $c_1^* > \bar{c} > c_2^*$.

Hence, on impact at time 0, the consumption jumps up causing current account to deteriorate as follows from (13). The current account deficit widens over time as net interest income on debt payments increase. The resulting current account deficits are financed by borrowings from abroad. Once the nominal interest rates return to their permanent higher level, i^H, households switch to a lower level of consumption, c_2^*. This is essentially Calvo's (1986) celebrated result that has been widely accepted as an explanation for the observed boom-bust consumption cycles during many ERBS plans. The framework is, however, unable to capture the empirically observed reserve and real interest rate movements discussed in the introduction. We now proceed to study ERBS plans under capital account restrictions: first, under anticipated restrictions, and next when the restrictions are unanticipated.

[8] There are two interpretations of T^* in the literature. The first is that T^* is simply a part of the announced government plan. The second interpretation perceives T^* as an endogenous outcome of a non-credible ERBS plan. As shown by Calvo and Végh (1993), our results would be consistent with either interpretation.

3.2 Consumption dynamics under capital account restrictions

In the temporary ERBS plan discussed above, we observed that the economy accumulates debt during $t \in [0, T^*)$. Let b^* be the level of foreign debt that households accumulate at the end of high consumption period under perfect capital mobility.

Suppose now, in addition, households anticipate that private capital transactions will be completely restricted once the economy-wide private debt level reaches an upper bound $\hat{b}$.[9] It is easy to see that as long as the debt limit $\hat{b} < b^*$, the restrictions will trigger. The logic behind this argument is simply as follows. Suppose there are no restrictions in place. Then the equilibrium consumption allocations will again be $\{c_1^*, c_2^*\}$. But, then, the private debt will reach $b^* > \hat{b}$, at the end of T^* which contradicts our assumption. Hence, the economy will enter capital account restrictions at some time $\hat{T} \in [0, T^*)$, where $\hat{T}$ is endogenously determined in the equilibrium.

We conjecture that if the restrictions do not trigger by T^*, the consumption path will follow the one that was discussed under Section 3.1.[10] Hence, the restrictions can occur beyond T^*. However, it is worth noting that $\hat{b} < b^*$ is a *sufficient but not necessary* condition for the restrictions to trigger before T^*. In Section 4.2, it is shown that the restrictions can come into existence even when $\hat{b} > b^*$.

Before capital account restrictions come into existence at $\hat{T}$, $\rho_t = \beta$. Then, (5), (6), and (19) imply that consumption will be constant for $t \in [0, \hat{T})$. Beyond $\hat{T}$, however, $b_t = \hat{b}$ for all t. Furthermore, in general $\rho_t \neq \beta$, which from (5), (6), and (19) implies that the consumption will have a dynamic path. To compute the path of consumption, we first combine the government's policy rules, (10) and (11), with economy's resource constraint,

[9] Note that $\hat{b}$ is exogenous in our framework. One could interpret $\hat{b}$ as the loan ceiling imposed by international lenders. (There have been many recent contributions in the literarure which have sought to explain these loan ceilings. See, for example, Kiyotaki and Moore (1997) and Aghion, Baccetta and Banerjee (2000).) In addition, when international lenders hit their loan ceilings, the government bans outflows. Alternatively, $\hat{b}$ can be part of a capital control scheme announced by the government. The results of our model are robust to either interpretation.

[10] For a formal proof, see footnote 12.

(12), to rewrite the latter as

$$\dot{m}_t = rm_t + y - c_t - r\left(\hat{b} + \bar{d}\right).$$

Then, substituting the cash-in-advance constraint, (3), into the above equation yields

$$\dot{c}_t = r_\alpha \left(c_t - \tilde{c}\right), \tag{20}$$

where $r_\alpha = r - \frac{1}{\alpha}$, and where $\tilde{c} = \frac{y - r\left(\hat{b} + \bar{d}\right)}{1 - r\alpha}$. We assume that $r_\alpha < 0$. Then, (20) implies that consumption monotonically travels towards its steady state $\tilde{c}$. Observe that under capital account restrictions, m_t is a predetermined variable since households can not reallocate their portfolio instantaneously, i.e., exchange money for bonds at the central bank. Any adjustment in real money balances has to be made over time by running current account deficits/surpluses. As a result of the cash-in-advance constraint, c_t is also a predetermined variable. Therefore, the initial condition for equation (20) equals the consumption which prevails an instant before the restrictions are imposed. Hence, the consumption follows the following time path

$$c_t = \begin{cases} \hat{c}, \quad t \in [0, \hat{T}), \\ \hat{c}e^{r_\alpha\left(t - \hat{T}\right)} + \tilde{c}\left(1 - e^{r_\alpha\left(t - \hat{T}\right)}\right), \quad t \in [\hat{T}, \infty). \end{cases} \tag{21}$$

Finally, note that $\hat{c} > \tilde{c}$. We formally show in the next section that on impact at time 0, consumption rises to $\hat{c}$ and stays at the same level up to $\hat{T}$, then monotonically declines to its steady state level, $\tilde{c}$.

3.3 Equilibrium under restrictions.

We now solve for the equilibrium value of the time, $\hat{T}$, when the restrictions are anticipated, along with the dynamic paths of consumption and real interest rates. To do so, we first obtain the path of the costate variable by combining (5) and (6):

$$\begin{aligned} \lambda_t &= \hat{\lambda} = \frac{u'\left(\hat{c}\right)}{1 + \alpha i^L}, \quad t \in [0, \hat{T}); \\ \dot{\lambda}_t &= \frac{1}{\alpha}\left(1 + \alpha\left(\beta + \epsilon_t\right)\right)\lambda_t - \frac{u'\left(c_t\right)}{\alpha}, \quad t \in [\hat{T}, \infty), \end{aligned} \tag{22}$$

where c_t is given by (21) and ϵ_t is given by (18). Note further that λ_t can not jump for any $t > 0$ since the future is perfectly anticipated. If $\hat{T}$ was known, then there is a unique $\hat{c}$, correspondingly a unique $\hat{\lambda}$ and a path of c_t from (21) that is consistent with (22). Hence, given a value of $\hat{T}$, $\hat{c}$ is obtained as a unique solution to (21) and (22).

Having computed $\hat{c}$ in the above step, and given the initial conditions of the stationary economy, $\bar{b}, \bar{h}, \bar{m}$, and $\bar{d}$, household's budget constraint (2) combined with policy rules (10) and (11) determines the time $\hat{T}$ when the private debt level hits $\hat{b}$. Then $\hat{c}$ uniquely determines $\hat{T}$ as

$$\hat{T} = \frac{1}{r} \ln \left(1 + r\alpha + r\frac{\hat{b} - \bar{b}}{\hat{c} - \bar{c}} \right) \tag{23}$$

Thus, given $\hat{b}$, equations (21) - (23) characterize a unique equilibrium under capital restrictions. Two features of equation (23) are noteworthy. First, if $\hat{b} = \bar{b}$, then, as shown in Section 4.1, the economy stays in the stationary state forever as it existed before time 0. In this case $c_t = \hat{c} = \bar{c}$. Hence, equation (23) is not applicable as it is indeterminate. However, it is clear that the restrictions bind from 0 onwards, i.e., $\hat{T} = 0$. Second, if $\hat{b} > \bar{b}$ then the household consumption $\hat{c} > \bar{c}$, and then $\hat{m} > \bar{m}$, since and hence $\hat{c} > \bar{c}$. Then, from (23), $\hat{T} > 0$. In this case, households' consumption over $t \in [0, \hat{T})$, $\hat{c}$, is larger than the stationary level, $\bar{c}$. In this period, the economy runs a current account deficit until the debt level reaches $\hat{b}$.

For further analysis, it is convenient to derive the dynamic path of the planar system in c_t and λ_t represented by (20) and (22). Appendix 8.1 shows that the dynamic system is saddle-path stable. Accordingly, the phase diagram is presented in Figure 2. Note first that in a world of free capital mobility, c_1^*, c_2^* and λ_t are determined by placing a horizontal line across the two $\dot{\lambda} = 0$ schedules. At T^* the consumption jumps from the right schedule to the left while λ_t remains constant. There are no other dynamics to be observed. However, with restrictions being triggered at $\hat{T} \in [0, T^*)$, there is another schedule $\dot{c} = 0$ that comes into existence from $\hat{T}$ onwards.

As seen in Figure 2, the restriction begins at $\hat{T} \in (0, T^*)$ in general. In this case, the dynamic path given by $A \rightarrow B \rightarrow SS$ in Figure 2 describes the equilibrium.[11] Observe that neither c_t nor λ_t can jump except at $\hat{T}$. Thus, at time 0, when the temporary stabilization policy is announced consumption

[11]The level of steady state consumption at SS, $\tilde{c}$ will be determined by $\hat{b}$. Thus the point

jumps to a value $\hat{c} > \bar{c}$. As has already been stated, $\hat{c} > \tilde{c}$, or else the first order conditions as well as the resource constraint will be violated. Since, the restrictions begin at $\hat{T} > 0$, $\lambda_t = \hat{\lambda}$, $c_t = \hat{c}$, and $\rho_t = \beta$, for all $t \in [0, \hat{T})$. Next, observe that at time $\hat{T}$, when the anticipated restrictions bind, c_t cannot jump. Similarly, λ_t can not jump. Hence, using (5), it follows that $\rho_t = \beta, \lambda_t = \hat{\lambda}$, and $c_t = \hat{c}$ at $t = \hat{T}$. Since λ_t will have a continuous path, it is clear that it must join its post-T^* saddle-path SP at $t = T^*$. Given its pre-T^* system and dynamics, as shown in Figure 2, it must follow a downward $\left(\dot{\lambda} < 0\right)$ path for all $t \in [\hat{T}, T^*)$. Note that any other path will diverge and never arrive at the saddle path. Finally, since the dynamic system must be on the saddle-path at T^*, no equilibrium with $\hat{T} > T^*$ exists.[12]

The dynamic path of λ_t implies movements in real interest rate from (6), which can be rewritten as

$$\rho_t = \beta - \frac{\dot{\lambda}}{\lambda_t}. \tag{24}$$

Observe that since $\dot{\lambda} < 0$ over $t \in [\hat{T}, T^*)$, $\rho_t > \beta$. In Appendix 8.2, we show that the dynamic path of c_t and ρ_t can be represented in a planar system which is saddle-path stable. Thus, as shown in Figure 3, ρ_t begins at β and then keeps rising for all $t \in [\hat{T}, T^*)$. However, it must be on the saddle path from $t = T^*$. At $t = T^*$, since ρ_t can jump while c_t and λ_t cannot, from (5) and (19) it follows that ρ_t drops down to a value less than β, as shown in Figure 3, and thereafter monotonically travels towards its steady state value β. Finally from (5), $\triangle\rho_{T^*} = \epsilon^L - \epsilon^H < 0$ for all $\hat{b}$ and $\hat{T}$.

As a result of the foregoing analysis, Figures 4A and 5A illustrate the dynamic paths of real interest rates and consumption, respectively. To summarize, a temporary ERBS plan announced at time 0 is expected to collapse at $t = T^*$ in the future. Households know with perfect foresight that the economy would be subject to complete capital account restriction at some point of time $\hat{T} \in [0, T^*)$, when the private debt level hits $\hat{b}$. As long as the inflation is low, agents prefer to consume a relatively higher amount. Given that there is perfect capital mobility until $t = \hat{T}$, they finance this consump-

SS will be different for each $\hat{b}$ and $\hat{T}$. However, for the sake of expositional convenience, we denote the steady state by the same point, SS, for all cases analyzed below.

[12]Formally, we rule out that the system may stay at a point like A' in Figure 2 for $t \in \left[T^*, \hat{T}\right]$. Suppose it does. Then, it will require a discrete downward jump in ρ_t at T^*. Since $\rho_t = \beta + \frac{\dot{\lambda}}{\lambda_t}$ and $\dot{\lambda} = 0$, this is impossible.

tion by borrowing in international capital markets. When the private debt levels reaches $\hat{b}$, agents are cut off from international capital markets. However, given that the stabilization is still in place, they continue to maintain their high consumption levels. Even after the stabilization ends, real interest rates remain low and rise only gradually, which induces agents to keep a relatively higher level of consumption and reduce it only gradually. The ensuing trade and current account deficits are then financed by running down the country's reserves.

Thus, the results mimic the stylized facts associated with stabilization plans. In particular, the analysis provides an explanation for the loss of reserves and the rise in real interest rates before the collapse of ERBS plans. In contrast with previous models of ERBS plans, our analysis draws a wedge between world and domestic real interest rates. Hence, agents' consumption allocations are substantially different than that obtained in a world of perfect mobility. The next section studies how the well-known consumption boom-bust cycles are affected by capital account restrictions.

4 Consumption boom-bust cycles

Our study of the dynamics for a general case of $\hat{T} \in (0, T^*)$ makes it clear that consumption cycles are robust to capital account restrictions. However, its magnitude relative to the perfect capital mobility case is likely to depend on the debt ceiling, $\hat{b}$, or implicitly on the time when the restrictions bind, $\hat{T}$. As has been discussed earlier a low value of $\hat{b}$ would imply that the restrictions are mainly on capital inflows. A high value of $\hat{b}$ on the other hand would imply that restrictions are essentially on capital outflows. The level of $\hat{b}$ therefore turns out to be crucial in determining consumption dynamics. In order to illustrate this point and contrast our results with the perfect capital mobility case, we specifically focus on the following two polar cases: when capital account restrictions bind at (a) $\hat{T} = 0$, and (b) $\hat{T} = T^*$. Since $\hat{T}$ is endogenously determined and depends on the debt ceiling, $\hat{b}$, we first need to characterize the levels of $\hat{b}$ that correspond to the each case.

4.1 Restrictions at $\hat{T} = 0$

For restrictions to begin immediately, the debt ceiling must equal the existing level of private debt, i.e. $\hat{b} = \bar{b}$. In Appendix 8.4, it is shown that the dynamic system is represented by $A'' \to SS$ in Figure 2. Clearly, $\hat{c} = \tilde{c} = \bar{c}$. As shown in Figure 2, λ_t jumps down on impact at time 0 and then monotonically travels to its steady state value $\tilde{\lambda}$ while consumption remains constant. As a result, the equilibrium real interest rate is higher than β and rises over time for $t \in [0,T^*)$, as shown in Figure 4B. Since there are no dynamics after T^*, ρ_t returns to its steady state value β at T^*.

A striking feature of this case is that consumption remains at its constant stationary level despite the temporariness of the ERBS plan. The intuition behind this result is simple. Given that the inflation is lower over $t \in [0,T^*)$, agents would like to consume a higher amount in this period. However, they are prevented from doing so because of the presence of capital account restrictions. The real interest rate rises, and a high real interest rate induces households to forego current consumption. Note that the shorter the remaining term of lower inflation, the higher is the incentive for the households to consume more, given that their initial asset position remains constant. However, a rising path of real interest rate ensures that households choose a flat path of consumption.

4.2 Restrictions at the end of the ERBS plan: $\hat{T} = T^*$

In this case, the dynamic system is represented by $A' \to SS$ in Figure 2. Both $\hat{c}$ and $\hat{\lambda}$ are shown by point A'. Under this scenario, the system is already on the saddle-path when restrictions are triggered. In Appendix 8.5, we show that controls come into existence at T^* only if $\hat{b} = \hat{b}^{T^*} > b^*$, i.e. the debt ceiling is above the debt level that would reach at the end of the ERBS plan under perfect capital mobility. Since controls begin only at T^*, $\rho_t = \beta$ for all $t \in [0, T^*)$. At T^*, ρ_t jumps down, and then asymptotically rises towards its steady state value β, as shown in Figure 4C.

The result that restrictions can be triggered even when $\hat{b} > b^*$ comes as a surprise. However, the result is intuitive once the equilibrium path of real interest rate is taken into account. Notice that the nominal interest rate is same as it is under perfect capital mobility for all $t \in [0, T^*)$. However, it remains lower relative to the perfect mobility case even after the plan collapses. Hence, the consumption boom relative to a free capital mobility world is *prolonged*. Observe further that under capital account restrictions, households can not borrow to finance consumption boom after T^*. They can only do so by accumulating real balance in advance. Thus, a higher consumption during $t \in [0, T^*)$, in addition, helps households sustain a high level of consumption beyond T^* by running down their real balances. Thus, consumption boom is further amplified. Figure 5B shows the resulting path of consumption.

Boom-bust amplification and its welfare implications It is easy to argue from continuity that ERBS equilibria with capital account restrictions exist for all $\hat{b} \in \left[\bar{b}, \hat{b}^{T^*}\right]$, and that $b^* \in \left(\bar{b}, \hat{b}^{T^*}\right)$. Note again that for $\hat{b} = \bar{b}$, $\hat{T} = 0$ and for $\hat{b} = \hat{b}^{T^*}$, $\hat{T} = T^*$. As can be easily seen from the phase diagram in Figure 2, we conjecture that the higher the debt ceiling the later the restrictions come into existence, i.e., $\hat{T}$ is increasing in $\hat{b}$.[13] Thus, for $\hat{b} = b^*$, $\hat{T} < T^*$. This result states that the maximum amount of borrowing that would have occurred under perfect capital mobility occurs earlier in a world with capital restrictions. The resulting path of consumption is shown in Figure 5C. Note that the path of consumption is consistent with the path of real interest rate shown in Figure 4A: $\rho > \beta$ for $t \in [\hat{T}, T^*)$ and $\rho < \beta$ for $t > T^*$. We observe that under capital restrictions, the consumption boom-bust cycle is amplified relative to the case under perfect capital mobility even though the amount of private debt accumulated at the end of the plan is same under the two equilibria. The intuition behind this result similar to the $\hat{T} = T^*$ case. Observe that on average the real interest rates are lower relative to the perfect capital mobility case. From Figure 5C, it is easy to conjecture that the welfare under capital account restrictions is lower than the welfare under perfect capital mobility even when the maximum debt level is same under the two scenarios.

In general, however, the closer $\hat{T}$ is to T^*, the more prolonged and amplified is the consumption boom cycle, since the real interest rates are lower on average. On the other hand, the closer $\hat{T}$ is to 0, the more subdued the boom-bust cycle is as the real interest rates are higher on average. It is easily seen that the first-best welfare is obtained when $\hat{b} = \bar{b}$ and $\hat{T} = 0$,

[13]This conjecture has been verified numerically. A formal proof, however, is left for the future.

and the worst welfare outcome occurs when $\hat{b} = \hat{b}^{T^*}$. Let us denote the time when restrictions bind for $\hat{b} = b^*$ as $\hat{T}^{b^*}$. Then, by continuity, there is a $\hat{T} = \hat{T}^{**} \in (0, \hat{T}^{b^*})$ corresponding to a $\hat{b} = \hat{b}^{**} \in (0, b^*)$, for which welfare under restrictions equals the welfare under a perfect capital mobility world.

Thus, we conjecture that for all $\hat{b} < \hat{b}^{**}$, capital restrictions improve welfare relative to the perfect capital mobility world in an ERBS plan, while opposite is the case for all $\hat{b} > \hat{b}^{**}$.

4.3 Self-fulfilling capital controls

From the results obtained in Sections 3.3 and 4.2, we conclude that temporary ERBS equilibria with capital account restrictions exist for all $\hat{b} \in \left[\bar{b}, \hat{b}^{T^*}\right]$, and that $b^* \in \left(\bar{b}, \hat{b}^{T^*}\right)$. Hence, for all $\hat{b} \in [b^*, \hat{b}^{T^*}]$ there are two distinct possibilities. If households do not anticipate restrictions, the allocations will be determined as in a world of free capital mobility. On the other hand, if households anticipate restrictions to be imposed at $\hat{T} \in [\hat{T}^{b^*}, T^*)$, where $\hat{T}^{b^*}$ is the time when restrictions are triggered for $\hat{b} = b^*$, there will be a corresponding level of $\hat{b} \in \left[b^*, \hat{b}^{T^*}\right]$, which will lead to an equilibrium with capital restrictions. Thus, there are two possible equilibria for all $\hat{b} \in [b^*, \hat{b}^{T^*}]$.

5 Unanticipated restrictions on capital flows

Extending the previous analysis to unanticipated capital account restrictions is straightforward. In particular, suppose the economy is undergoing an ERBS plan, in which agents anticipate perfect capital mobility to exist forever. At $t = \hat{T} \in [0, T^*)$, there is a sudden unanticipated stop of capital inflows and at the same time the government bans capital outflows. Note that $c_t = c_1^*$ for all $t \in [0, \hat{T})$, where c_1^* is the level of consumption over $t \in [0, T^*)$ in our benchmark model with perfect capital mobility. Note further that when households are slapped with unanticipated restrictions, they can not adjust their real balances. Therefore, the level of consumption at $\hat{T}$ is $\hat{c} = c_1^*$. Thereafter, the path of consumption is given by equation (21), where $\tilde{c} = \frac{y - r\left(\hat{b} + \bar{d}\right)}{1 - r\alpha}$ and where $\hat{b}$ is obtained from (23) after substituting $\hat{c} = c_1^*$ since $\hat{T}$ is known now. The path of λ_t is given by (22) as before. After combining the two systems, the trajectory $U \to U' \to U'' \to SS$ in Figure

2 shows the dynamic path of c_t and λ_t. Note that for $t < \hat{T}$, the system is at U. Thus, on impact at $\hat{T}$, λ_t jumps down to its new value at U' and then declines over $t \in [\hat{T}, T^*)$ to join the saddle path at T^*. Accordingly, the path of real interest rates is then determined from (24).

Qualitatively, the paths of real interest rate and consumption remain as shown in Figure 4A and Figure 5A, respectively. The real interest rate $\rho_t > \beta$, for all $t \in [\hat{T}, T^*)$, and $\rho_t < \beta$ for all $t \in [T^*, \infty)$. Ideally, the household would like to consume more over $t \in [\hat{T}, T^*)$. However, since capital *inflows* are restricted, the real interest rates are high and the consumption, as a result, is lower than that without restrictions. On the other hand, for $t \in [T^*, \infty)$, it is *outflows* that are implicitly restricted, thereby lowering real interest rates. This induces households to consume more than they would without restrictions. However, unlike the case when the restrictions are anticipated, the consumption boom cycle is now trivially determined by the dynamics under perfect capital mobility. It is obvious that whether the steady-state post-collapse consumption is lower than that under perfect capital mobility will be determined by the time when the restrictions come into existence.

6 Empirical Evidence

6.1 Description of Data and Variables

This section attempts to empirically examine the theoretical conclusions derived in the previous sections by focusing on the pattern of reserve losses and real interest rates under ERBS plans before the crisis. Specifically, we investigate whether current account deficits coupled with restrictions on capital inflows can account for reserve and real interest rate movement patterns prior to the collapse of the exchange rate regime. All data for the variables used in the study are available in quarterly frequency in *International Financial Statistics*, IMF. Given this data set, our goal is to identify 'tranquil' periods of ERBS plan prior to its collapse and then to study the dynamics of reserve losses and real interest rates in relations to other variables. However, as it is not easy to identify all stabilization plans, we consider the following four alternative samples and check for the robustness of our findings in these samples. Among all country data available from 1975 to 2001, we have taken all non-OECD and non-former Eastern European country data. We have only included non-OECD economies since the ERBS programs have mainly occurred in these economies and since it is likely that their programs are subject to credibility issues. Furthermore, these economies are more vulnerable to capital account restrictions. The former Eastern European countries are excluded as they usually have had restrictions on capital flows throughout the sample period considered. Sample 1 defined as 'stable exchange rate regime' is obtained by further limiting the sample to countries and periods where the rates of change in the exchange rate were less than 5 percent per quarter.[14] This sample will include and cover most of the 'tranquil' periods of ERBS program prior to its collapse. The sample includes a pooled time-series data of 33 developing economies from 1975 to 2001.[15]

Sample 2 defined as 'fixed exchange rate regime' is obtained by further limiting the sample to the countries and periods where the rates of change in the exchange rate were less than 1 percent per quarter. This sample will capture 'tranquil' periods of ERBS programs with fixed exchange rate. Sample 3 defined as 'ERBS regime' is obtained based on the episodes of ERBS identified in Easterly (1996), Hamann (2001), and Calvo and Végh (1999). Based on the data availability, Sample 3 includes nine ERBS episodes in five countries (Argentina, Brazil, Iceland, Israel, and Mexico).[16] Sample 4 defined as 'full sample' is the sum of Sample 1 and Sample 3.

As the theoretical discussion in the previous section suggests that the continued current account deficits under ERBS plan may result in persistent reserve losses and a significant rise in real interest rates prior to the collapse

[14]Since Frankel and Rose (1996) and Milesi-Ferretti and Razin (1998) use annual exchange rate depreciation vis-a-vis the dollar of 25 percent as a basis to identify currency crisis, we have translated this criterion to quarterly frequency with conservatism to identify 'tranquil' periods.

[15]The country sample is restricted by the availability of the quarterly data for our variables of interest. The list of 33 developing economies is as follows : Argentina, Bahamas, Bangladesh, Bolivia, Brazil, Chile, Colombia, El Salvador, Ethiopia, Guatemala, Hong Kong, India, Indonesia, Israel, Jordan, Korea, Mexico, Myanmar, Nepal, Pakistan, Panama, Papua New Guinea, Peru, Philippines, Seychelles, Sri Lanka, Sudan, Suriname, Thailand, Tonga, Vanuatu, Venezuela, and Zimbabwe.

[16]The episodes included in this study are Argentina during 1979Q4 to 1980Q4, 1986Q2 to 1986Q4, 1992Q1 to 2001Q4, Brazil for 1986Q3, Mexico during 1989Q2 to 1994Q4, Iceland for 1984Q3, Israel during 1986Q2 to 1986Q4, 1990Q3 to 1991Q1, and 1992Q2 to 1998Q3. Initial three quarters of each of the identified periods of ERBS episodes described in Calvo and Vegh (1999) are dropped, since the initial stages of ERBS program may suffer from the lagged carry-over effects from the previous periods of instability.

of stable exchange rate regime when there is an exogenous shock limiting the external borrowing capacity, we examine the probability of significant and persistent reserve losses and that of a rise in real interest rate when an economy experiences chronic current account deficits and a drop in short-term capital inflow.

In order to capture significant and persistent losses of foreign exchange reserves, an indicator function, $IRES$, is constructed so that the function takes a value of 1 if country's reserves denominated in US dollar decline more than 5% for the current and the next quarter or 10% for the current quarter. Otherwise, the indicator function is zero. The criterion of 5% decline for two consecutive quarters will cover episodes of persistent losses in reserves and the criterion of 10% decline will capture episodes where the reserve losses occur in a dramatic way. To check for the robustness of the results under different criteria, following alternative definitions are used in the sensitivity analysis as well: $IRES2$, the function takes a value of 1 if country's reserves decline more than 5% for the current and the next quarter, and zero otherwise; $IRES3$, the function takes a value of 1 if country's reserves decline more than 10% for the current quarter and decline in the next quarter, and zero otherwise.

A significant rise in real interest rate is represented by an indicator function, $IRRATE$, where the function takes a value of 1 if the annualized real interest rate rises by more than 50 percentage points for the current and the next quarter. Otherwise, the indicator function is zero. Real interest rate is calculated by short-term treasury bill rate minus the expected inflation rate which is proxied by the change in the CPI from the current to the next quarter.[17]

To measure the degree of continued current account deficit, we have taken the average ratio of the current account to GDP of the current and three previous quarters (CA_GDP).[18] To proxy for the slowdown of capital inflows potentially reflecting introduction of borrowing constraint, an indicator function for a sharp decline in portfolio investment inflow ($IPORT$) is

[17] Alternative indicator functions with a rise of 25 percentage points for two consecutive quarters or with a rise of 100 percentage points for two consecutive quarters were also considered which resulted in the same qualitative findings. The results are available upon request.

[18] We have also considered alternative definitions of the averages of ratios with longer time length up to 8 quarters. The results are available upon request.

constructed so that the function takes a value of 1 if the portfolio investment inflows denominated in US dollar decline more than 60% for the current quarter, and zero otherwise. To additionally consider persistent and significant reduction in short-term capital inflows, an alternative definition, $IPORT2$, is also considered in the sensitivity analysis where the function takes a value of 1 if the portfolio investment inflows decline more than 60% for the current quarter or 30% for the current and the one previous quarter, and zero otherwise.[19] An interaction term of CA_GDP and $IPORT$ (or $IPORT2$) with strong negative values may reflect a stop in capital flows in a country experiencing chronic current account deficits.

Other control variables which may influence the probability of significant and persistent reserve losses are considered. Averages ratios of portfolio investment inflows to GDP of four previous quarters (PT_GDP) are constructed to see how the degree of exposure to short-term capital inflows affects the probability of reserve losses. The average differential of domestic and US interest rates for four previous quarters ($DINTR$) are also considered. The interest rate differential is used to capture the degree of capital flow immobility across borders.

6.2 Empirical Analysis

This subsection presents empirical evidence on whether current account deficit and a sudden drop in short-term capital inflow increase the probability of significant and persistent reserve losses and the probability of a significant increase in real interest rates prior to the collapse of ERBS programs controlling for other variables based on the pooled time-series quarterly data of the four alternative samples described in the previous subsection. As discussed in the data subsection, the sample periods are limited to the 'tranquil' exchange rate periods in order to examine the dynamics of variables prior to the potential exchange rate collapse. We estimate probit models using maximum likelihood estimation with $IRES$ and with $IRRATE$ as the dependent variables to examine the relationships among current account deficits, a sudden drop in short-term capital inflow, changes in reserves, and changes in

[19] Our results were also robust to an alternative definition, $IPORT3$, where the function takes a value of 1 when the portfolio investment inflows decline more than 80% for the current quarter or 40% for the current and the one previous quarter, and zero otherwise. The results are available upon request.

real interest rates.

The probit regression results with $IRES$ as a dependent variable based on Sample 1 are presented in Table 1. Models (i) and (ii) indicate that CA_GDP is statistically significant in influencing $IRES$. The negative slope derivative estimates are consistent with the implications of our theoretical model where economies having high current account deficits to GDP ratios are subject to potential episodes of reserve losses under stable exchange rates. The slope estimate for $IPORT$ is positive and also significant in model (ii). Most importantly, the interaction terms of CA_GDP and $IPORT$ in models (iii), (iv), (v), and (vi) are robustly significant and have negative slope estimates. This finding suggests that reserve loss is likely when a country experiences a chronic current account deficit with a drop in the portfolio investment inflows. This supports our theoretical prediction on the pattern of reserve losses. Inclusions of the interaction term of CA_GDP and $IPORT$ in models (iii) and (iv) result in loss of significance for CA_GDP and $IPORT$ possibly due to the presence of multicollinearity problem or possibly due to the fact that the independent effects of the two variables become insignificant once the interaction term is introduced. In models (iv) - (vi), other control variables are included to check the robustness of our main results. Average ratios of portfolio investment to GDP (PT_GDP) show strong and significantly negative relation with $IRES$ in models (iv) - (vi), suggesting that the higher exposure to short-term capital inflows in the previous quarters may lower the chances of reserve losses as higher exposure may indicate relatively smaller restrictions in the capital market allowing easier access to foreign capital. The effect of $DINTR$ is found to be significant and positive in model (vi), implying that the differential in the interest rates will raise the probability of reserve losses as it reflects the degree of capital flow immobility.

Table 2 presents sensitivity analysis based on the model (vi) of Table 1 considering alternative samples and definitions of variables. The models (i), (ii), and (iii) show regression results based on Sample 2 (fixed exchange rate regime), Sample 3 (ERBS regime), and Sample 4 (full sample), respectively. The interaction terms of CA_GDP and $IPORT$ are strongly significant and have negative slope estimates for all models, confirming our main findings of the model (vi) in Table 1. The models (iv) and (v) in Table 2 use alternative definitions of reserve loss indicator functions, $IRES2$ and $IRES3$, respectively, and the model (vi) uses an alternative definition of short-term capital flow decline indicator function, $IPORT2$, all based on Sample 4. Our main finding on the interactive term of CA_GDP and $IPORT$ is strongly supported in these three models. Average ratios of portfolio investment to GDP (PT_GDP) and average interest differentials ($DINTR$) have negative and positive signs in all models of Table 2, respectively. PT_GDP is statistically significant in all models except for the model (v) and $DINTR$ is statistically significant in all models except for the model (i) and (iv).

The probit regression results with $IRRATE$ as a dependent variable are presented in Table 3. As with the regressions with $IRES$, the interaction terms of CA_GDP and $IPORT$ in models (i) and (ii) based on Sample 1 are significant and have negative slope estimates. This finding suggests that a rise in real interest rate is likely when a country experiences a chronic current account deficit with a drop in the portfolio investment inflows. This supports our theoretical prediction on the pattern of real interest rates. The models (iii), (iv), and (v) show regression results based on Sample 2 (fixed exchange rate regime), Sample 3 (ERBS regime), and Sample 4 (full sample), respectively. Although the interaction term of CA_GDP and $IPORT$ is statistically significant only for Sample 1 and 4, it has negative slope estimates for all models, confirming our main finding. Average ratios of portfolio investment to GDP (PT_GDP) do not show significance in all models. The findings in this section provide some empirical evidence supporting our main theoretical implication on the pattern of significant and persistent reserve losses and real interest rates during 'tranquil' periods of ERBS program given an unanticipated capital flow shock.

7 Conclusions

The stylized facts observed in the ERBS episodes have been widely documented in the literature. While the literature has mainly focused on consumption boom-bust cycle and the associated real exchange rate dynamics, it has been largely silent on the real interest rate and reserve movements. In this study, we seek to provide evidence and account for these additional features. We also seek to examine the consequences of capital account restrictions on consumption patterns. Specifically we seek to explore the impact of such restrictions on the boom-bust cycle.

The model and the cases analyzed clearly demonstrate that introduction of capital account restrictions to the imperfect credibility framework provides a much richer set of dynamics which are more consistent with a number of the recent episodes of ERBS. In addition to reproducing consumption boom-bust cycle, the model is better able to mimic reserve losses and rise in real interest rates that have been observed in the data. Interestingly we find that the introduction of capital account restrictions could potentially amplify the boom-bust cycle observed in the imperfect credibility framework. Further, we find that even when the debt ceiling is high enough such that it would not have been reached under perfect capital mobility, anticipated restrictions can be self-fulfilling. Hence, anticipated capital restrictions could lead to 'overborrowing' relative to the case when capital is perfectly mobile.

Furthermore, the empirical evidence based on probit model regressions supports the implications of our theoretical framework, as the main findings robustly show that the chronic current account deficits and a drop in the portfolio investment inflows raise the probability of the significant and persistent reserve losses and a rise in real interest rates during the 'tranquil' periods of ERBS programs.

8 Appendix

8.1 The planar system in c_t and λ_t

Equations (20) and (22), repeated below for convenience, describe a planar system in c_t and λ_t:

$$\begin{aligned}\dot{c}_t &= r_\alpha \left(c_t - \tilde{c}\right), \\ \dot{\lambda}_t &= \frac{1}{\alpha}\left(1 + \alpha\left(\beta + \epsilon_t\right)\right)\lambda_t - \frac{u'\left(c_t\right)}{\alpha}, \quad t \in [\hat{T}, \infty).\end{aligned}$$

where $\epsilon_t = \epsilon^L, t \in [0, T^*)$, and $\epsilon_t = \epsilon^H, t > T^*$. Linearizing around the steady state, $c_t = \tilde{c}$; $\lambda_{ss} = \frac{u'(\tilde{c})}{(1+\alpha(\beta+\epsilon_t))}$, gives the following system

$$\begin{bmatrix} \dot{c}_t \\ \dot{\lambda}_t \end{bmatrix} = \begin{bmatrix} r_\alpha < 0 & 0 \\ \frac{1}{\alpha}\left(1 + \alpha\left(\beta + \epsilon_t\right)\right) > 0 & -\frac{u''(\tilde{c})}{\alpha} > 0 \end{bmatrix} \begin{bmatrix} c_t - \tilde{c} \\ \lambda_t - \tilde{\lambda} \end{bmatrix}. \tag{25}$$

Let the two eigenvalues be μ_1 and μ_2. Then $\mu_1\mu_2 = (1 - r\alpha)\, u''\left(\tilde{c}\right) < 0$; $\mu_1 + \mu_2 = r - \frac{u''(\tilde{c})+1}{\alpha}$. Thus, the system has one positive and one negative eigenvalue. Hence, it is saddle-path stable. Figure 2 shows the phase diagram for the dynamic system in c_t and λ_t for $t \in [0, T^*)$ and $t > T^*$.

8.2 The planar system in c_t and ρ_t

Differentiating (5) with respect to time yields

$$u''(c_t)\,\dot{c}_t = \dot{\lambda}_t\,(1+\alpha(\rho_t+\epsilon_t)) + \lambda_t\alpha\dot{\rho}_t, \tag{26}$$

where $\epsilon_t = \epsilon^L, t \in [0, T^*)$, and $\epsilon_t = \epsilon^H, t > T^*$. Substituting (5), (6), and (20), into (26) yields

$$\dot{\rho}_t = \frac{1}{\alpha}\left(\rho_t - \beta + r_\alpha c_t \frac{u''(c_t)}{u'(c_t)}\left(1 - \frac{\tilde{c}}{c_t}\right)\right)(1+\alpha(\rho_t+\epsilon_t)).$$

Linearizing around the steady state ($c_t = \tilde{c}$; and $\rho_t = \beta$) gives the following system

$$\begin{bmatrix} \dot{c}_t \\ \dot{\rho}_t \end{bmatrix} = \begin{bmatrix} r_\alpha < 0 & 0 \\ \frac{u''(\tilde{c})}{u'(\tilde{c})}\frac{1}{\alpha}(1+\alpha(\beta+\epsilon_t))\,r_\alpha > 0 & \frac{1}{\alpha}(1+\alpha(\beta+\epsilon_t)) > 0 \end{bmatrix} \begin{bmatrix} c_t - \tilde{c} \\ \rho_t - \beta \end{bmatrix}. \tag{27}$$

Let the eigenvalues be ω_1 and ω_2. From (27), it can be seen that $\omega_1\omega_2 = -(1+\alpha(\beta+\epsilon_t))(1-r\alpha) < 0$; and $\omega_1+\omega_2 = \beta+\epsilon_t > 0$. Hence, the system is saddle-path stable. Figure 3 shows the phase diagrams for the dynamic system in c_t and ρ_t for $t \in [0, T^*)$ and $t > T^*$.[20]

8.3 Upper and lower bounds for $\hat{b}$

8.4 $\hat{T} = 0$

Clearly $\hat{T} = 0$ if and only if the restrictions bind right from time 0, i.e., private sector debt is fixed at its existing level, $\hat{b} = \bar{b}$. Then $\hat{m} = \bar{m}$ and $\hat{c} = \bar{c}$. Moreover, $\tilde{c} = \bar{c}$. Hence, from (21) $c_t = \bar{c}\ \forall\ t$. Then from (22) and (18), it can be shown that

$$\lambda_t = \bar{\lambda}\left(1 - \frac{\alpha\left(\epsilon^H - \epsilon^L\right)}{1+\alpha i^H} e^{\left(\frac{1+\alpha i^L}{\alpha}\right)(t-T^*)}\right). \tag{28}$$

[20] Note that both $\dot{c} = 0$ and $\dot{\rho} = 0$ graphs are independent of ϵ_t. However, the slope of saddle-path will be different in both cases. Further note that, for both ϵ^H and ϵ^L, the saddle path will lie in the same quadrant.

Hence, on impact at time 0, λ_t drops from its stationary value $\bar{\lambda}$ to $\hat{\lambda} = \bar{\lambda}\left(1 - \frac{\alpha\left(\epsilon^H - \epsilon^L\right)}{1+\alpha i^H} e^{-\frac{1+\alpha i^L}{\alpha}T^*}\right)$ and then monotonically follows (28) to arrive at $\tilde{\lambda} = \bar{\lambda}\frac{1+\alpha i^L}{1+\alpha i^H} = \frac{u'(\bar{c})}{1+\alpha i^H}$ at $t = T^*$. Note that there are no dynamics after T^*. Since $\rho_t = \beta - \frac{\dot{\lambda}_t}{\lambda_t}$, it is implied that $\rho_t > \beta$ for $t \in (0, T^*)$, and $\rho_t = \beta$, for $t > T^*$. Further, it follows from (22) and (28) that $\frac{\dot{\lambda}}{\lambda} < 0$, and that $\frac{\dot{\lambda}}{\lambda}$ is declining over time since c_t is constant. Hence, from (24) ρ_t rises over $t \in [0, T^*)$ before falling to its steady state value β at T^*.

8.5 $\hat{T} = T^*$

Here we show that $\hat{T} = T^*$ only if $\hat{b} = \hat{b}^{T^*} > b^*$. The proof pursues the following logic. In Step I, we show that the saddle-path equilibrium requires that $\ddot{\lambda}_t \leq 0$. Step II shows that $\ddot{\lambda}_{T^*} \leq 0$ requires an upper bound for $\frac{\tilde{c}}{\hat{c}}$. Next, in Step III, we show that $\frac{\tilde{c}}{\hat{c}}$ for $\hat{b} = b^*$ violates this upper bound. Finally, noting that given $\hat{T} = T^*$, $\frac{\tilde{c}}{\hat{c}}$ is decreasing in $\hat{b}$. Hence, $\hat{T} = T^*$ only if $\hat{b} > b^*$.

For analytical convenience we assume a CES utility form in what follows. Formally, $u(c) = \frac{c^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}}$, where σ is the elasticity of substitution.

Step I: For $\hat{T} = T^*$, (22) can be rewritten as

$$\begin{aligned} \hat{\lambda} &= \frac{u'(\hat{c})}{1+\alpha\, i^L}, \quad t \in [0, T^*), \\ \dot{\lambda}_t &= \frac{1}{\alpha}\left(1+\alpha\, i^H\right)\lambda_t - \frac{u'(c_t)}{\alpha}, \quad t \in [T^*, \infty), \end{aligned} \tag{29}$$

Differentiating the law of motion of λ_t over $t \in [T^*, \infty)$ with respect to time yields

$$\ddot{\lambda}_t = \frac{1}{\alpha}\left(1+\alpha\, i^H\right)\dot{\lambda}_t - \frac{u''(c_t)}{\alpha}\dot{c}_t, \tag{30}$$

Equation (30) describes a first order differential equation in $\dot{\lambda}_t$, with its initial value at $\dot{\lambda}_{T^*} = u'(\hat{c})\frac{\epsilon^H - \epsilon^L}{1+\alpha i^L} > 0$ and $\lim_{t\to\infty}\dot{\lambda}_t = 0$. Moreover, the second term in (30) is monotonically increasing with time. Differentiating the second term in (30) with respect to time and using the CES utility function with (21) yields

$$\frac{d}{dt}\left(-\frac{u''(c_t)}{\alpha}\dot{c}_t\right) = \frac{r_\alpha}{\sigma\alpha}c_t^{-\frac{1}{\sigma}-2}\left(\tilde{c} - \frac{1}{\sigma}(c_t - \tilde{c})\right)\dot{c}_t \geq 0,$$

since it can be shown that $\tilde{c} \geq \frac{1}{\sigma}(c_t - \tilde{c}), \forall\, \sigma$. Thus, $\dot{\lambda}_t$ monotonically declines from λ_{T^*} to 0 over time. Hence $\ddot{\lambda}_t \leq 0$.

Step II: Using (21) in (29) and (30) yields

$$\begin{aligned} \dot{\lambda}_{T^*} &= u'(\hat{c}) \frac{\epsilon^H - \epsilon^L}{1+\alpha\, i^L}, \\ \ddot{\lambda}_{T^*} &= \frac{1}{\alpha}\left(1+\alpha\, i^H\right)\dot{\lambda}_{T^*} - \frac{u''(\hat{c})}{\alpha}\dot{c}_{T^*} \\ &= \frac{u'(\hat{c})}{\alpha}\left(\frac{1+\alpha\, i^H}{1+\alpha\, i^L}\left(\epsilon^H-\epsilon^L\right) + \frac{r_\alpha}{\sigma}\left(1-\frac{\tilde{c}}{\hat{c}}\right)\right). \end{aligned} \tag{31}$$

Hence, $\ddot{\lambda}_{T^*} \leq 0$ if and only if $\frac{1+\alpha\, i^H}{1+\alpha\, i^L}\left(\epsilon^H-\epsilon^L\right) + \frac{r_\alpha}{\sigma}\left(1-\frac{\tilde{c}}{\hat{c}}\right) < 0$. This implies an upper bound for $\frac{\tilde{c}}{\hat{c}}$.

Step III: Suppose $\hat{b} = b^*$. Then (23) implies that $\hat{c} = c_1^*$. From (14), (16), and (19), it is easy to show that $c_1^* = \frac{\bar{c}}{\left(1-e^{-rT^*}(1-\phi)\right)}$, where $\phi = \left(\frac{1+\alpha\, i^L}{1+\alpha\, i^H}\right)^\sigma$. Using (23) again obtains a value of b^*, which in turn yields $\tilde{c} = \frac{\bar{c}}{(1-r\alpha)}\frac{\phi - r\alpha}{\left(1-e^{-rT^*}(1-\phi)\right)}$. Hence $\frac{\tilde{c}}{\hat{c}} = \frac{\phi-r\alpha}{1-r\alpha}$. Substituting the last result in (31) yields

$$\ddot{\lambda}_{T^*} = \frac{u'(\hat{c})}{\alpha}\left(\frac{1+\alpha\, i^H}{1+\alpha\, i^L}\left(\epsilon^H-\epsilon^L\right) - \frac{1-\phi}{\alpha\sigma}\right).$$

Let $x = \frac{1+\alpha i^L}{1+\alpha i^H} < 1$. Then rewrite the terms within brackets as

$$\frac{1+\alpha\, i^H}{1+\alpha\, i^L}\left(\epsilon^H-\epsilon^L\right) - \frac{1-\phi}{\alpha\sigma} = \frac{1}{\alpha}\left(\left(1+\alpha\, i^H\right)\frac{1-x}{x} - \frac{1-x^\sigma}{\sigma}\right).$$

Note that $\left(1+\alpha\, i^H\right)\frac{1-x}{x} - \frac{1-x^\sigma}{\sigma} \geq 0$ if $\frac{1-x}{x} - \frac{1-x^\sigma}{\sigma} \geq 0$ or if

$$x^{\sigma+1} - x + \sigma(1-x) > 0. \tag{32}$$

For $\sigma = 0$, the left hand side in (32) equals zero while for $\sigma \to \infty$ it is positive and unbounded. Moreover, differentiating the LHS in (32) with respect to σ yields

$$\frac{d}{d\sigma}\left(x^{\sigma+1} - x + \sigma(1-x)\right) = x^{\sigma+1}\ln(1+\sigma) + (1-x) > 0.$$

Thus, $x^{\sigma+1} - x + \sigma(1-x) > 0$, $\forall\ \sigma > 0$. Hence, $\ddot{\lambda}_{T^*} > 0$, $\forall\ \sigma > 0$.

STEP IV: As shown in the previous step, $\ddot{\lambda}_{T^*} > 0$ if $\hat{b} = b^*$. Hence, for the system to begin on the saddle-path at T^* it is required that $\frac{\tilde{c}}{\hat{c}}$ be lower than that implied if $\hat{b} = b^*$, as evident from (31). As $\frac{\tilde{c}}{\hat{c}}$ is decreasing in $\hat{b}$ it implies that $\hat{T} = T^*$ only if $\hat{b} > b^*$. Let this value be denoted by $\hat{b}^{T^*}$.

8.5.1 The time path of ρ_t when $\hat{T} = T^*$

Since controls come into existence only at T^*, $\rho_t = \beta$, $t \in [0, T^*)$. Since $\frac{\dot{\lambda}}{\lambda_t} > 0$ for $t > T^*$, it follows that ρ_t jumps below β at T^* and then asymptotically rises towards β over time.

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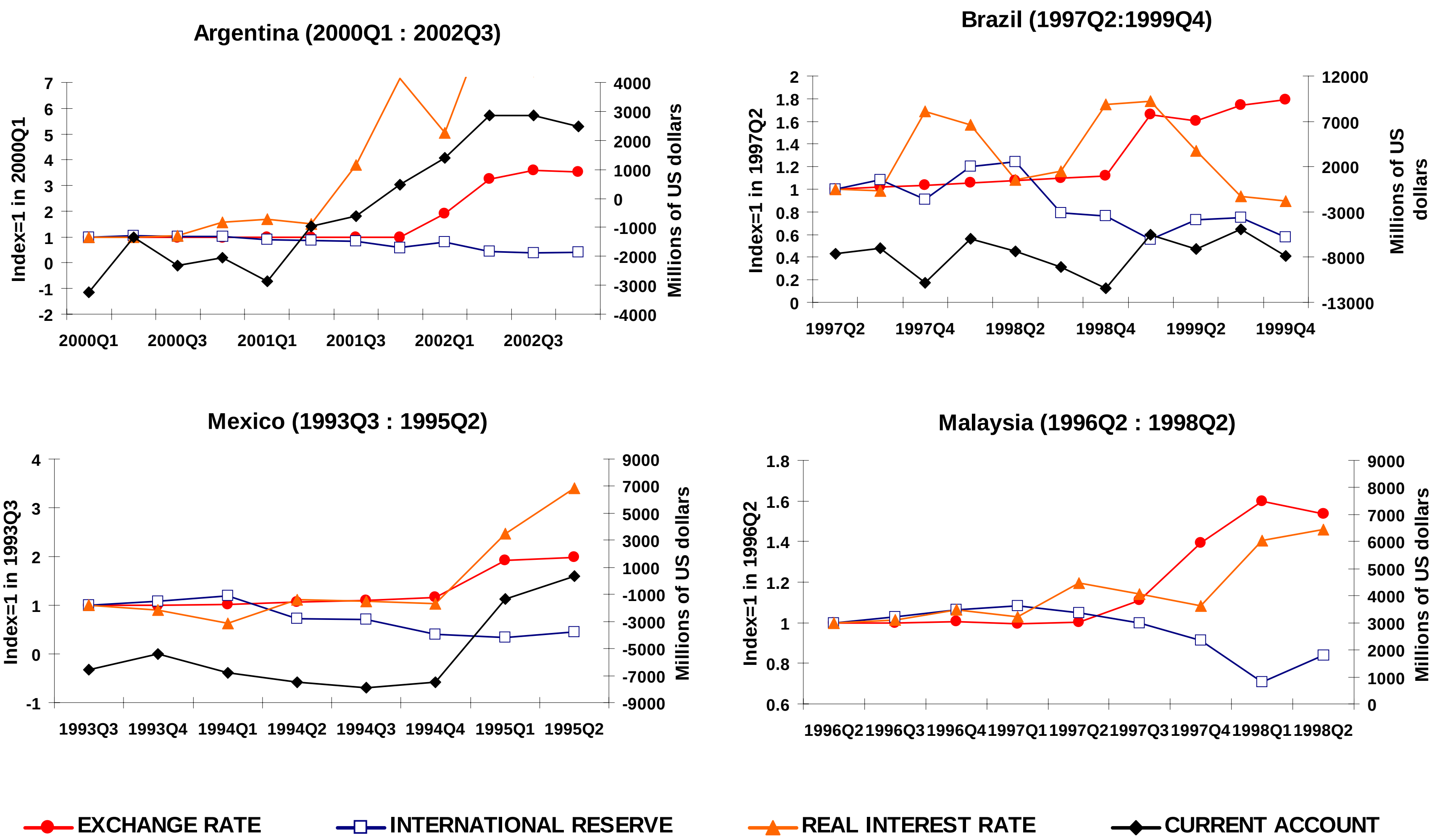
Figure 1



Source: International Financial Statistics, IMF

Note: Exchange rates, international reserves, and real interest rates are normalized to 1 at the respective initial period considered in each figure. The real interest rates are calculated using the current and one period forward index of CPI. The three variables follow the left scale. Current accounts are in millions of current US dollars and follow the right scale.

Figure 2

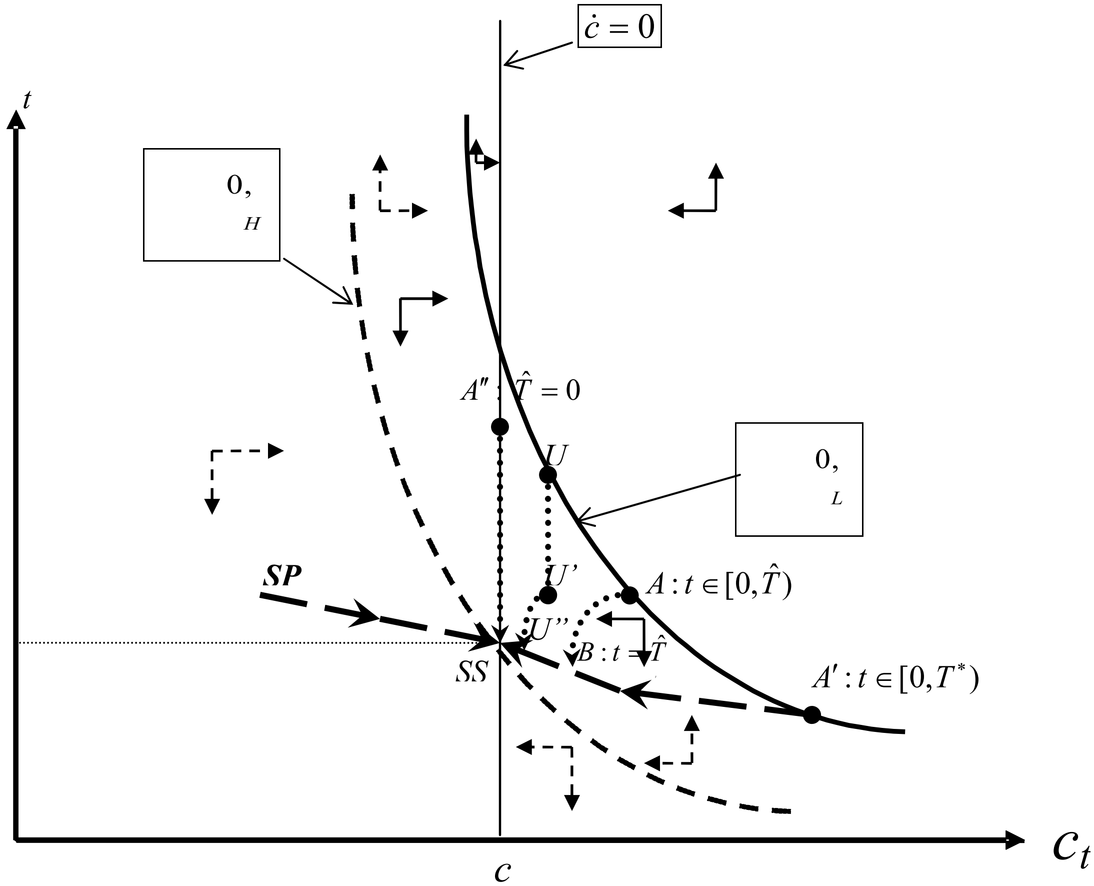


Figure 3

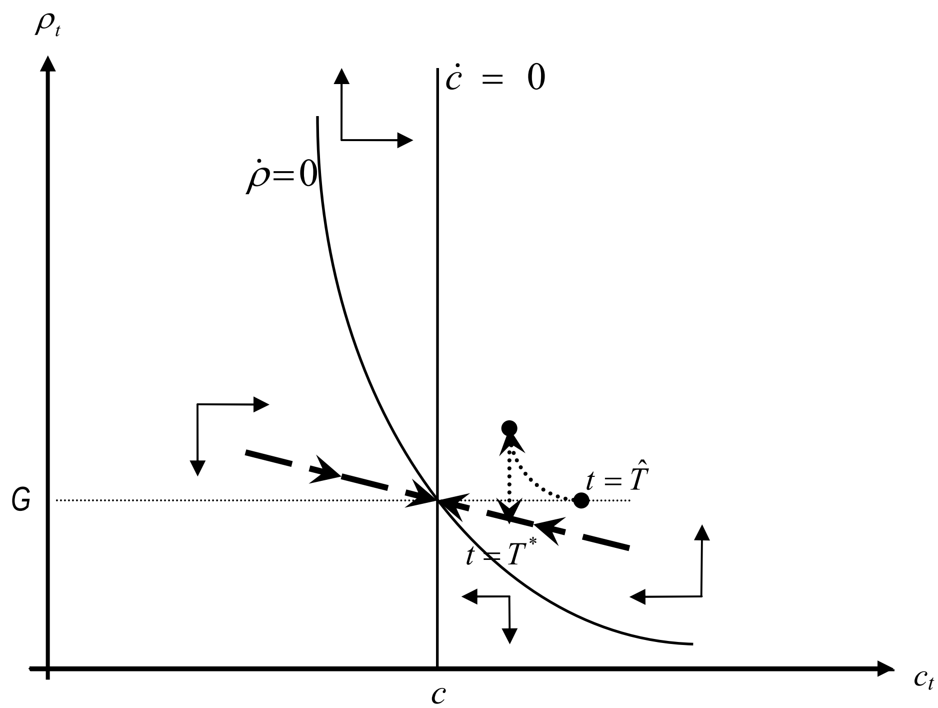


Figure 4A

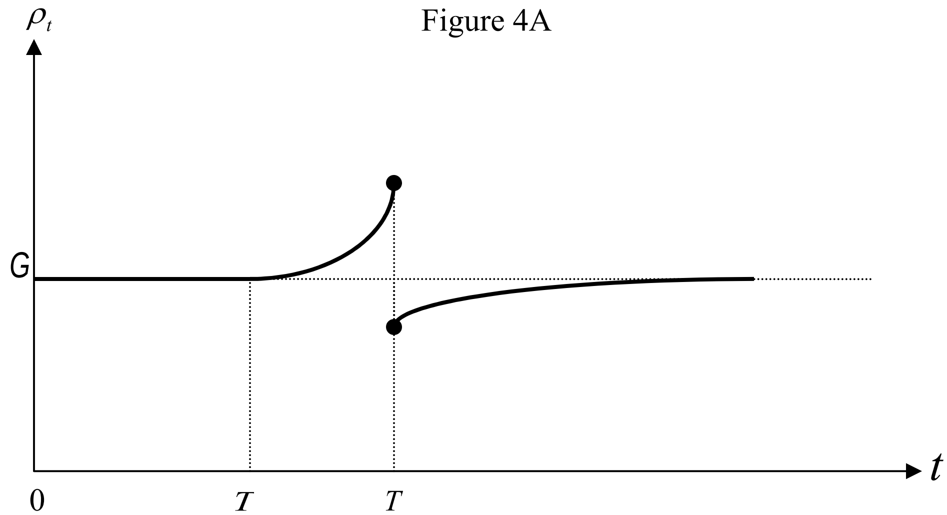


Figure 4B

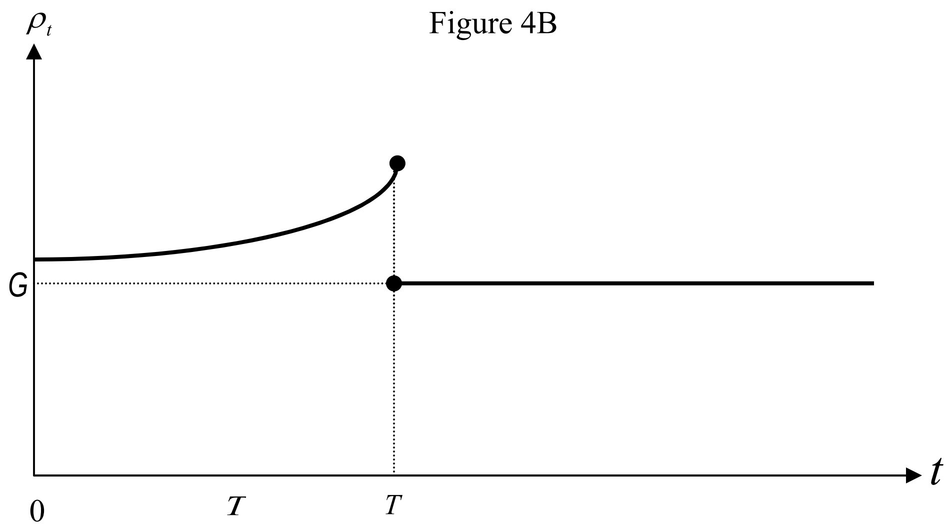


Figure 4C

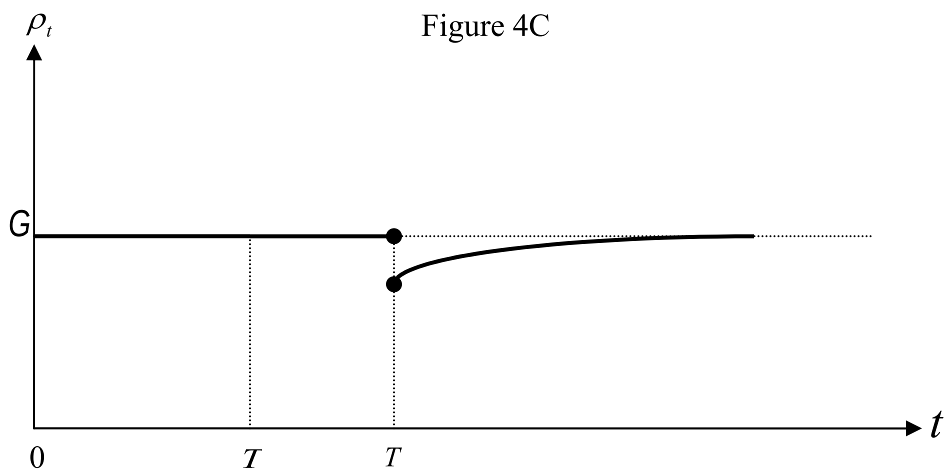


Figure 5A

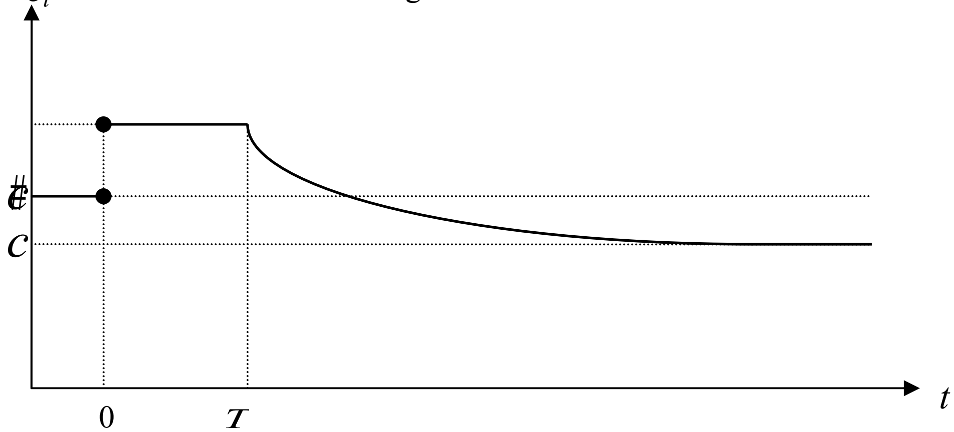


Figure 5B

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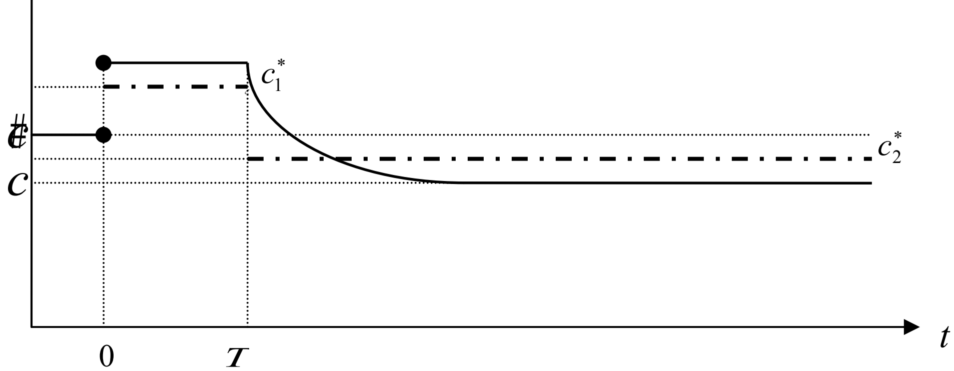

Figure 5C

b b

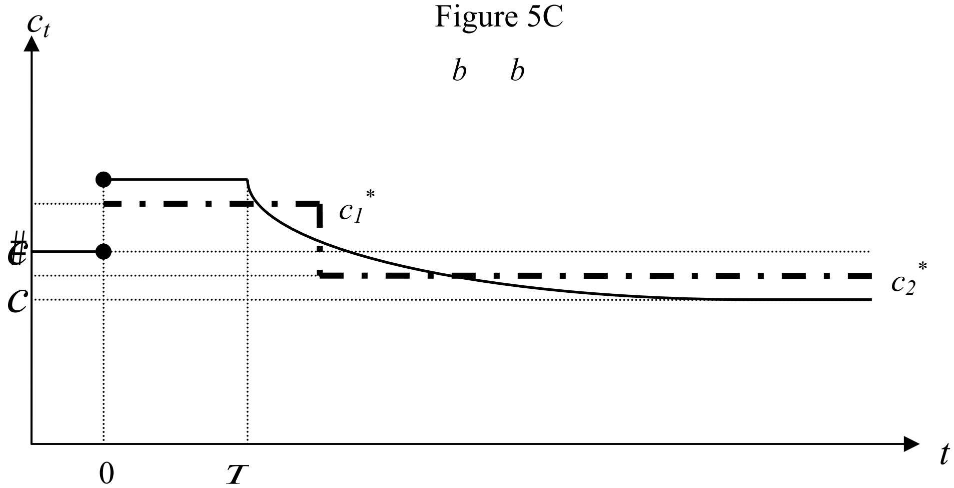

TABLE 1: Probit Regression on Probability of Significant and Persistent Reserve Losses: Samples under Stable Exchange Rate Regime

Dependent Variable: IRES	Sample: Sample1 (stable exchange rate regime)											
	(i)		(ii)		(iii)		(iv)		(v)		(vi)	
Parameter	**dP/dx**	**z**	**dP/dx**	**z**	**dP/dx**	**z**	**dP/dx**	**z**	**dP/dx**	**z**	**dP/dx**	**z**
Constant	-0.261	-20.761***	-0.266	-15.665***	-0.251	-14.489***	-0.227	-12.017***	-0.226	-15.034***	-0.229	-13.387***
CA_GDP	-0.950	-4.436***	-0.579	-1.751*	-0.155	-0.412	0.095	0.227				
IPORT			0.050	1.645*	-0.007	-0.159	0.025	0.612				
IPORT*CA_GDP					-1.873	-2.143**	-1.604	-1.797*	-1.861	-2.834***	-2.042	-2.950***
PT_GDP							-1.843	-2.378**	-1.779	-2.336**	-2.524	-2.670***
DINTR											0.001	2.158**
Observations	1620		829		827		651		651		588	
No. of positive obs.	345		122		122		87		87		77	
Pseudo R^2	0.012		0.007		0.013		0.024		0.023		0.043	
LR chi-squared statistics [p-value]	20.245	[.000]	5.593	[.061]	10.996	[.012]	15.593	[.004]	15.075	[.001]	25.257	[.000]

Notes: Probit regression using maximum likelihood estimation. The table reports probit slope derivatives (and associated z-statistics for hypothesis of no effect) multiplied by 100. Dependent variable IRES is an indicator function for significant and persistent losses of foreign exchange reserves and takes the value 1 if there is a reserve loss at time t, and zero otherwise. CA_GDP is an average ratio of the current account to GDP of the current and three previous quarters, IPORT is an indicator function for a sharp decline in portfolio investment inflow, PT_GDP is an average ratio of portfolio investment inflow to GDP of four previous quarters, and DINTR is an average differential of domestic and US interest rates for four previous quarters. Details of these variables are provided in Section 5. *, **, *** represent significance at 10, 5, and 1 percent levels, respectively.

TABLE 2: Sensitivity Analysis: Alternative Samples and Alternative Definitions for Indicator Functions

Sample	Sample2 (fixed)		Sample 3 (ERBS)		Sample 4 (full)		Sample 4 (full)		Sample 4 (full)		Sample 4 (full)	
Dependent Variable	IRES		IRES		IRES		IRES2		IRES3		IRES	
	(i)		(ii)		(iii)		(iv)		(v)		(vi)	
Parameter	**dP/dx**	**z**	**dP/dx**	**z**	**dP/dx**	**z**	**dP/dx**	**z**	**dP/dx**	**z**	**dP/dx**	**z**
Constant	-0.200	-9.184 ***	-0.208	-5.190 ***	-0.238	-13.731***	-0.160	-15.981***	-0.169	-15.340***	-0.238	-13.725 ***
IPORT*CA_GDP	-2.169	-2.377 **	-7.425	-3.711 ***	-2.424	-3.539***	-0.989	-2.285**	-1.138	-2.825***		
IPORT2*CA_GDP											-2.408	-3.519 ***
PT_GDP	-4.105	-3.162 ***	-3.691	-2.118 **	-1.864	-2.127**	-1.443	-2.143**	-0.697	-1.228	-1.898	-2.164 **
DINTR	0.001	1.521	0.002	1.946 *	0.001	2.223**	0.000	1.047	0.001	3.040***	0.001	2.224 **
Observations	279		85		592		592		592		592	
No. of positive obs.	32		11		79		30		30		79	
Pseudo R^2	0.071		0.281		0.043		0.017		0.038		0.043	
LR chi-squared statistics [p-value]	19.637	[.000]	22.816	[.000]	25.428	[.000]	9.754	[.021]	21.983	[.000]	25.295	[.000]

Notes: Probit regression using maximum likelihood estimation. The table reports probit slope derivatives (and associated z-statistics for hypothesis of no effect) multiplied by 100. Dependent variable IRES, IRES2, and IRES3 are indicator functions for significant and persistent losses of foreign exchange reserves and takes the value 1 if there is a reserve loss at time t, and zero otherwise. CA_GDP is an average ratio of the current account to GDP of the current and three previous quarters, IPORT and IPORT2 are indicator functions for a sharp decline in portfolio investment inflow, PT_GDP is an average ratio of portfolio investment inflow to GDP of four previous quarters, and DINTR is an average differential of domestic and US interest rates for four previous quarters. Details of these variables are provided in Section 5. *, **, *** represent significance at 10, 5, and 1 percent levels, respectively.

TABLE 3: Probit Regression on Probability of Significant Rise in Real Interest Rate

Dependent Variable: IRRATE

	Sample 1 (stable)		Sample1 (stable)		Sample 2 (fixed)		Sample 3 (ERBS)		Sample 4 (full)	
	(i)		(ii)		(iii)		(iv)		(v)	
Parameter	**dP/dx**	**z**	**dP/dx**	**z**	**dP/dx**	**z**	**dP/dx**	**z**	**dP/dx**	**z**
Constant	-1.099	-12.079***	-1.140	-15.193***	-1.149	-10.506***	-1.149	-5.333***	-1.129	-15.131***
CA_GDP	1.619	0.830								
IPORT	-0.046	-0.215								
IPORT*CA_GDP	-8.988	-1.997**	-7.307	-2.272**	-4.178	-0.913	-14.994	-1.487	-6.762	-2.142**
PT_GDP	-2.143	-0.778	-2.209	-0.792	-1.751	-0.610	-3.085	-0.553	-2.621	-0.916
Observations	595		595		283		89		599	
No. of positive obs.	77		77		35		12		78	
Pseudo R^2	0.012		0.011		0.005		0.024		0.010	
LR chi-squared statistics [p-value]	7.061 [.133]		6.381 [.041]		1.447 [.485]		2.133 [.344]		5.954 [.051]	

Notes: Probit regression using maximum likelihood estimation. The table reports probit slope derivatives (and associated z-statistics for hypothesis of no effect) multiplied by 100. Dependent variable IRRATE is an indicator function for a significant rise in real interest rate and takes the value 1 if there is a rise in real interest rate at time t, and zero otherwise. CA_GDP is an average ratio of the current account to GDP of the current and three previous quarters, IPORT is an indicator function for a sharp decline in portfolio investment inflow and PT_GDP is an average ratio of portfolio investment inflow to GDP of four previous quarters. Details of these variables are provided in Section 5. *, **, *** represent significance at 10, 5, and 1 percent levels, respectively.