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# Using Balance Sheet Data to Identify Sovereign Default and Devaluation Risk.*

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The relationship between devaluation and default risk is a central issue in the discussion of the costs and benefits of dollarizing emerging economies. Correct measures of these two unobserved variables are essential for assessing the welfare implications of dollarization. This paper studies the role of private sector balance sheets in measuring devaluation and default risk.

A leading argument in favor of dollarization rests on the causal link between devaluation risk and country default risk. According to this view, "firms and households in emerging economies have dollar-denominated debts, some of them acquired through domestic transactions like the purchase of a car or a refrigerator. Therefore, fluctuations in the exchange rate run the risk of creating serious financial stress." (Calvo, 2000). As devaluations cause defaults, dollarization can substantially reduce default risk in emerging economies by taking

*We thank Rodolfo Campos for valuable research assistance. We also wish to thank comments from participants at the UTDT Conference on Dollarization and at the V Annual Meeting of LACEA in Rio, 2000.

away the government's ability to devalue. Assessing the empirical relevance of this argument requires the analyst to measure devaluation and sovereign risk.

In our interpretation of the argument, the chain through which devaluations lead to defaults has two crucial links: the liability dollarization problem (net dollar liabilities and net peso assets) and explicit or implicit government bailouts designed to avoid generalized bankruptcy. This is the way in which the story goes. Assume that, under certain unexplained circumstances (an exogenous fiscal shock?), a government must devalue while private sector balance sheets exhibit a liability dollarization problem. Under these conditions following a devaluation the credit market will collapse. To avoid the supposedly costly generalized default, the government may have to make transfers to banks. If this transfers are sufficiently high, the government may have to default on its debt. If this is the way the world functions, then when the (exogenous in the story) expected devaluation goes up, the expected default will go up. A minimal empirical test that this theory should pass is a positive correlation between expected devaluation and default risk.

The standard approach to measuring sovereign default risk and devaluation risk rests on two no-arbitrage conditions restricting the return on peso denominated (emerging) sovereign bonds and the return on dollar denominated (emerging) sovereign bonds on one hand, and the return on dollar denominated (emerging) sovereign bonds and the return on dollar denominated risk free bonds on the other. The absence of risk free peso denominated bonds creates an identification problem as there are two arbitrage equations to measure three unobserved variables: sovereign default risk on peso bonds, sovereign default risk on dollar bonds, and devaluation risk.[1]

[1]An implicit assumption in the literature, that we maintan in the paper is that the US government never

This paper shows that the identification problem can be solved with information about government and private sector balance sheets and a simple of the shelf model of optimal default and devaluation. The model provides a theory on how a benevolent government jointly decides the three default alternatives it has available, namely, the devaluation rate, the default rate on peso denominated bonds and the default rate on dollar denominated bonds. A key assumption of the model, motivated by the current debate on dollarization, is that government guarantees banks a minimum level of profits. This implies that if there is a currency mismatch in private sector balance sheets that would induce banks to go bankrupt in the event of a large devaluation, banks (depositors) will be bailed out by the government.

The model predicts that the choice between defaulting on domestic currency debt through an explicit default or through devaluation depends on the private sector's balance sheet positions. In general, government will prefer to default on its domestic currency debt by devaluing its currency rather than through an explicit default. The incentive to do so stems from the fact that a devaluation is more profitable because it amounts to a default on the government's domestic currency debt *plus* its monetary liabilities. In economies with a liability dollarization problem, where the private sector has net dollar liabilities (or net peso assets), governments may choose to explicitly default on domestic currency debt instead of devaluing. This is because, in this case, the devaluation will trigger a bailout of the banking system. The optimal choice between devaluation and explicit default will depend on the trade-off between the fiscal gain of depreciating government monetary liabilities and the fiscal cost of bailing out the financial system. If the latter exceeds the former, the government

defaults. Thus, if the US government were to issue peso denominated bonds, we would have three interest rate differentials to identify the three unobesrved risks.

will prefer to default on its domestic debt, rather than devaluing and triggering a bailout.

Using data on Argentine balance sheets for the period 1994-2000 we find that it is never optimal for the government to default on its domestic currency debt when we take currency denomination of balance sheets at face value. Using this identifying assumption expected devaluations are measured by the difference between the return on domestic currency sovereign bonds and the risk free dollar rate. If we assume that all non-secured loans denominated in dollars are actually in pesos this result is reversed: it is never optimal for a government to devalue since a devaluation will trigger a financial crisis and, therefore, a bank-bailout that will offset the fiscal gain of devaluing.

## 1. The Identification Problem without an Optimizing Government.

The standard approach to look at the correlation between sovereign default risk and devaluation risk rests on the linearized no-arbitrage restrictions,

$$
(1) \qquad \begin{aligned} i_t - i_t^* &= E\delta_{t+1} + E\varepsilon_{t+1} - E\delta_{t+1}^* \\ i_t^* - r_t &= E\delta_{t+1}^* \end{aligned}
$$

where $i$ and $i^*$ are the interest rate on dollar and peso denominated sovereign debt, $r$ is the risk free dollar rate, $\delta^*$ and $\delta$ are the repudiation rates of dollar and peso denominated sovereign debt and $\epsilon$ is the devaluation rate. For simplicity, we assume that agents are risk-neutral. The identification problem arises because these two equations and the interest rate data are insufficient to uncover the unobserved variables of interest: $E\delta_{t+1}$, $E\varepsilon_{t+1}$, and $E\delta_{t+1}^*$.

Alternative assumptions on the government's default policy have very different implications for the interpretation of the data. Consider first the case in which the government always defaults on domestic and foreign currency debt simultaneously: $\delta_t = \delta_t^*$ for all $t$. Under this assumption,

$$
\begin{aligned}
i_t - i_t^* &= E\varepsilon_{t+1} \\
i_t^* - r_t &= E\delta_{t+1}^*,
\end{aligned}
$$

so the the currency spread and the sovereign spread reveal the devaluation risk and the default risk on foreign currency sovereign bonds. Alternatively, consider the case in which the government never defaults on domestic currency sovereign debt explicitly, but it does so implicitly by devaluing. In this case, $\delta_t = 0$ for all $t$,

$$
\begin{aligned}
i_t - r_t &= E\varepsilon_{t+1} \\
i_t^* - r_t &= E\delta_{t+1}^*.
\end{aligned}
$$

The covariance between $i_t - i_t^*$ and $i_t^* - r_t$ is

$$
\begin{aligned}
cov\left(i_t - i_t^*, i_t^* - r_t\right) &= cov\left(E\delta_{t+1} + E\varepsilon_{t+1} - E\delta_{t+1}^*, E\delta_{t+1}^*\right) \\
&= cov\left(E\varepsilon_{t+1}, E\delta_{t+1}^*\right) + \\
&\quad \left[cov\left(E\delta_{t+1}, E\delta_{t+1}^*\right) - var\left(E\delta_{t+1}^*\right)\right]
\end{aligned}
$$

In the first case with $\delta_t = \delta_t^*$, $cov\left(i_t - i_t^*, i_t^* - r_t\right) = 0$ implies that the case for dollarization is weak because in the data there is no relation between currency and sovereign default risk on foreign currency debt. In the second case, the same observation implies that $cov\left(E\varepsilon_{t+1}, E\delta_{t+1}^*\right) = var\left(E\delta_{t+1}^*\right) > 0$, so the case for dollarization is consistent with the data.

The next section addresses this identification problem by studying a simple dynamic Ramsey problem for a government that chooses devaluation rates, default rates, and guarantees a minimum profit to banks. The theory will tell us when is the government going to default on its domestic currency debt explicitly through repudiation or implicitly through devaluation.

## 2. Sovereign Default and Devaluation in a Ramsey Problem with Bank Bailouts.

As we mentioned in the introduction, we want to study the choice of default rates a government will set were it, for reasons we do not explain, chose to default. To do this, we need a theory of government behavior. Following the approach of Lucas and Stokey (1983) We assume that the government is benevolent and maximizes social welfare. The main advantage of this choice is that these models have been widely analyzed in the literature; to the extent that our approach was to check the consistency of the story with of-the-shelf models, this seems a natural choice. In addition, we will not explain why the government chooses to bail-out the private sector, we will just impose that it will in our model, to keep our analysis in line with the story, that takes the bail-out as given. Finally, we allow the government to default only once. The natural way to do it in the context of the optimal policy literature, is to solve a Ramsey problem with commitment. This leaves the government the additional degree of freedom at the beginning, where its choices will be determined by the exogenously given initial private sector balance sheet. Thus, all the action is determined by initial balance sheet positions, which are exogenous, as they are in the story that motivates our paper. Introducing dynamic considerations to allow for balance sheet positions to be determined in an equilibrium with default and modelling government's incentives to bail-out banks is well beyond the scope of this paper.

We study the decision problem faced by the government of a small open economy that, at time $t = 0$, must finance a given stream of government expenditures choosing a sequences of income tax rates, exchange rates and default rates on debts it inherits from the past. We assume that there is a fixed exchange rate regime in which government commits to exchange any amount of domestic and foreign currency at pre-announced exchange rates. A second key assumption of our model is that the government guarantees a minimum level of profits to the banking system. It is assumed throughout the exercise that this government can perfectly commit to future policies.

**A. Economic environment and definition of equilibrium.**

At each date, the state of the economy is denoted by $s_t$, where $\pi(s_t)$ is its probability.

There are two goods produced with the linear **technology**,

$$\begin{aligned} y_{1t} &= n_{1t} \\ y_{2t} &= n_{2t} \end{aligned}$$

where $y_{it}, n_{it}$ denote output and labor for goods $i = 1, 2$. Good 1 is not traded internationally and good 2 is. Purchasing power parity holds for the traded good

**Firms** choose labor inputs to maximize

$$(2) \quad p_{1t}y_{1t} + e_t p_{2t}^* y_{2t} - w_t(n_{1t} + n_{2t}).$$

subject to $n_{1t}, n_{2t} \geq 0$. $e_t, w_t, p_{1t}$ are the domestic currency prices of foreign currency, labor, the non-traded good. $p^*_{2t}$ is the foreign currency price of the traded good. This problem has an interior solution only if

$$p_{1t} = e_t p^*_{2t} = w_t \quad \text{for all } t.$$

Other possibilities will not be considered[2].

Household preferences over these two goods and work effort, $n_t$, are described by the utility function

$$(3) \quad \sum_{t=0}^{\infty} \beta^t E\left[u\left(c_{1t}\right) + u\left(c_{2t}\right) - \alpha n_t\right],$$

where $0 < \beta < 1$, $\alpha > 0$, $u : R \rightarrow R$ is monotonically increasing, concave, and satisfies $\lim_{x \rightarrow 0} u'\left(x\right) = \infty$ and $\lim_{x \rightarrow \infty} u\left(x\right) = 0$.

Purchases of the non-tradable good $c_{1t}$ have to be paid with domestic cash, while those of $c_{2t}$ can be paid with credit. The cash in advance constraint for good 1 is

$$(4) \quad p_{1t} c_{1t} \leq M_t \qquad \text{for all } t.$$

[2] This without loss of generality because there are no equilibria with corner solutions.

Household's budget constraints are given by

$$\left(B_t^H + M_t + D_t - L_t\right) + e_t\left(B_t^{H*} + D_t^* - L_t^*\right) \leq$$
$$M_{t-1} + \left(1 + i_{t-1}^b\right)\left(1 - \delta_t\left(s_t\right)\right) B_{t-1}^H + \left(1 + i_{t-1}\right)\left(D_{t-1} - L_{t-1}\right)$$
$$+ e_t\left(1 + i_{t-1}^{b*}\right)\left(1 - \delta_t^*\left(s_t\right)\right) B_{t-1}^{H*} + \left(1 + i_{t-1}^*\right)\left(D_{t-1}^* - L_{t-1}^*\right)$$
$$\Pi_t + p_{1t} g + w_t\left(1 - \tau_t\right) n_t - p_{1t} c_{1t} - p_{2t}^* e_t c_{2t}$$

for all $s_t$ and $t = 0, 1, 2, ...$where $B_t^H$, $B_t^{H*}$ are one period bonds held by households from $t$ to $t+1$ in domestic and foreign currency, respectively, $M_t$ are end of period money balances, $D_t, D_t^*, L_t, L_t^*$ are domestic and foreign currency denominated end of period bank deposits and loans, $g$ are government transfers, $\tau_t$ are income tax rates, and $\Pi_t$ are bank profits. $0 \leq \delta_0, \delta_0^* \leq 1$ represent default rates on domestic and foreign bonds at time 0.

In addition to the flow budget constraint above, households are restricted by a no Ponzi game condition.

**Financial intermediaries** costlessly receive deposits and lend money to the government and to the private sector. End of period balance sheets are described by

$$L_t + e_t L_t^* + B_t^b + e_t B_t^{b*} = D_t + e_t D_t^* \quad \text{for } t = -1, 0, 1, \ldots$$

and bank profits are

$$\begin{aligned}\Pi_t &= \left(1 + i_{t-1}^b\right)\left(1 - \delta\left(s_t\right)\right) B_{t-1}^b + \left(1 + i_{t-1}\right)\left(L_{t-1} - D_{t-1}\right) \\ &\quad + e_t\left(1 + i_{t-1}^{b*}\right)\left(1 - \delta^*\left(s_t\right)\right) B_{t-1}^{b*} + \left(1 + i_{t-1}\right)\left(L_{t-1}^* - D_{t-1}^*\right) + T_t \quad \text{for } t = 0, 1, 2, \ldots\end{aligned}$$

$T_t$ is a transfer scheme that guarantees banks a minimum level of profits. In our case this level of profits is zero, but we can easily accommodate any constant. The transfer scheme is

$$T_t = \max\left\{-\Pi_t + T_t, 0\right\}$$

A government insurance protects the banking system from aggregate shocks such as devaluations and sovereign defaults. The rule is meant to capture in a simple way the contingent debt nature of banks negative profits for the government.

Perfect foresight and no arbitrage conditions imply that bank profits and bailouts are zero for all $t \geq 1$. Bank bailouts at $t = 0$ are

$$\begin{aligned} T_0\left(e_0, \delta_0, \delta_0^*\right) &= \max\left\{\left(1+i_{t-1}^b\right)\left(1-\delta\left(s_t\right)\right)B_{t-1}^b + \left(1+i_{t-1}\right)\left(L_{t-1} - D_{t-1}\right) + \right. \\ &\quad \left. e_t\left(1+i_{t-1}^{b*}\right)\left(1-\delta^*\left(s_t\right)\right)B_{t-1}^{b*} + \left(1+i_{t-1}\right)\left(L_{t-1}^* - D_{t-1}^*\right), 0\right\}, \end{aligned}$$

Observe that defaults on government bonds may cause transfers to banks. Also, liability dollarization in the banking system makes the transfers that occur when banks have negative profits an increasing function of the exchange rate.

**The government** has to service its debt and pay for transfers to banks and households by levying income taxes, issuing money and by choosing repudiation rates on its liabilities.

Let $B_t^{g*}, B_t^g$ be government bond holdings. Government's budget constraints are

$$e_0 B_0^{g*} + B_0^g - M_0 = (1 + i_{-1})(1 - \delta_0) B_{-1}^g - M_{-1}$$
$$+ e_0 \left(1 + i_{-1}^*\right)(1 - \delta_0^*) B_{-1}^{g*} + \tau_0 \omega_0 n_0 - p_{10} g_0 - T_0$$

in the first period, and

$$e_t B_t^{g*} + B_t^g - M_t = (1 + i_{t-1}) B_{t-1}^g - M_{t-1}$$
$$+ e_t \left(1 + i_{t-1}^*\right) B_{t-1}^{g*} + \tau_t \omega_t n_t - p_{1t} g$$

for $t = 1, 2, \ldots$. The no Ponzi game condition is

$$\lim_{t\to\infty} \beta^{t+1} \frac{e_{t+1} B_{t+1}^{g*} + B_{t+1}^g - M_{t+1}}{e_{t+1} p_{2,t+1}^*} \geq 0.$$

For simplicity, assume the foreign government follows the **Friedman rule** for monetary policy—i.e.

$$\begin{aligned} i_t^* &= 0 \text{ for } t = -1, 0, 1, \ldots \\ p_{2t}^* &= \beta^t \text{ for } t = 0, 1, \ldots \end{aligned}$$

for $t = 0, 1, 2, \ldots$..To normalize, we also assume that $e_{-1} = 1, i_{-1} = 0$.

A consequence of this assumption is that an equilibrium exists only if exchange rates satisfy

$$(5) \quad e_{t+1} \geq e_t \text{ for all } t.$$

Otherwise, interest on domestic bonds will be negative, creating an arbitrage opportunity.

Combining household's and government's flow budget constraints, the no Ponzi game condition, expressions for bank profits, and the Friedman rule assumption for foreign monetary policy, we obtain

$$(6) \quad \sum_{t=0}^{t} \beta^t \left[ c_{1t} + c_{2t} + \left(1 - \frac{e_t}{e_{t+1}}\right) \frac{M_t}{p_{1t}} - (1-\tau_t)\, n_t - g \right] \leq$$
$$\frac{M_{-1} + (1-\delta_0)\left(B_{-1}^{H} + B_{-1}^{B}\right)}{e_0} + (1-\delta_0^*)\left(B_{-1}^{H*} + B_{-1}^{B*}\right) + \frac{T_0\left(e_0, \delta_0, \delta_0^*\right)}{e_0}$$

for households, and

$$(7) \quad \sum_{t=0}^{\infty} \beta^t \left[ g - \left(1 - \frac{e_t}{e_{t+1}}\right) \frac{M_t}{p_{1t}} - \tau_t n_t \right] \leq$$
$$(1-\delta_0) \frac{B_{-1}^{g} - M_{-1}}{e_0} + (1-\delta_0^*)\, B_{-1}^{g*} - \frac{T_0\left(e_0, \delta_0, \delta_0^*\right)}{e_0}$$

for the government.

Adding the government's and the household's budget constraint we obtain the country's budget constraint,

$$(8) \quad \sum_{t=0}^{\infty} \beta^t \left( (c_{1t} - n_{1t}) + (c_{2t} - n_{2t}) \right) \;\leq\; (1-\delta_0) \frac{B_{-1}^{H} + B_{-1}^{B} + B_{-1}^{g}}{e_0}$$
$$+ (1-\delta_0^*)\left(B_{-1}^{H*} + B_{-1}^{B*} + B_{-1}^{g*}\right)$$

**Market clearing** for the non–internationally-traded good, labor and bonds requires

$$\begin{aligned}
&\text{(9a)} & n_{1t} &= c_{1t} \quad \text{for all } t \\
&\text{(9b)} & n_{1t} + n_{2t} &= n_t \quad \text{for all } t \\
&\text{(9c)} & B^H_{-1} + B^B_{-1} + B^g_{-1} &= 0 \quad \text{for all } t \\
&\text{(9d)} & B^{H*}_{-1} + B^{B*}_{-1} + B^{g*}_{-1} + B^{F*}_{-1} &= 0 \quad \text{for all } t
\end{aligned}$$

We assume that all domestic currency bonds are held domestically. Thus, when markets clear the government budget constraint becomes

$$\text{(10)} \quad \sum_{t=0}^{\infty} \beta^t \left(c_{2t} - y_{2t}\right) \leq \left(1 - \delta_0^*\right) \left(B^{H*}_{-1} + B^{B*}_{-1} + B^{g*}_{-1}\right)$$

This equation states that the present value of the country's trade deficits equal the country's initial non-defaulted net foreign assets.

Denote initial portfolios as

$$I_0 = \left\{ M_{-1}, B^H_{-1}, B^B_{-1}, B^G_{-1}, D_{-1}, L_{-1}, B^{*H}_{-1}, B^{*B}_{-1}, B^{*G}_{-1}, D^*_{-1}, L^*_{-1} \right\}.$$

For given initial portfolios $I_0$, an allocation $\{c_{1t}, c_{2t}, n_{1t}, n_{2t}, M_t\}_{t=0}^{\infty}$ is a **competitive equilibrium with bank bailouts, taxes and default** if, and only if,

(i) consumers maximize utility (3) subject to budget (6) and cash-in-advance (4) constraints,

(ii) government policies $\{\delta_0, \delta_0^*\}$ and $\{g, , \tau_t, e_t\}_{t=0}^{\infty}$ are consistent with the government's budget constraint (7) and the non-negativity of domestic currency interest rates (5),

(iii) firms solve (2),

(iv) the market clearing conditions (9) are satisfied.

**Household's problem**. The first order conditions of the household's problem for $t = 0, 1, 2, .......$ are

$$
\begin{aligned}
(11) \quad \frac{u'(c_{1t})}{u'(c_{2t})} &= \left(1 + \left(1 - \frac{e_t}{e_{t+1}}\right)\right) \\
\frac{\alpha}{u'(c_{2t})} &= (1 - \tau_t)
\end{aligned}
$$

and

$$
\begin{aligned}
(12a) \quad M_t &= p_{1t} c_{1t} \\
(12b) \quad c_2 &= (1 - \beta) a_0 + g \\
&\quad + (1 - \beta) \sum_{t=0}^{t} \beta^t \left[ (1 - \tau_t) n_t - c_{1t} - \left(1 - \frac{e_t}{e_{t+1}}\right) \frac{M_t}{e_t p_{2t}^*} \right]
\end{aligned}
$$

where

$$
a_0 = \frac{M_{-1} + (1 - \delta_0)\left(B_{-1}^H + B_{-1}^B\right)}{e_0} + (1 - \delta_0^*)\left(B_{-1}^{H*} + B_{-1}^{B*}\right) + \frac{T(\delta_0, \delta_0^*, e_0)}{e_0}
$$

The household's optimality conditions, the non-negativity of interest rates (5), and the budget constraint (6) yield the implementability conditions

$$(13)\quad u'(c_2)\left[(1-\beta)\,a_0^H+g\right]+(1-\beta)\sum_{t=0}^{t}\beta^t\left[\alpha n_t-u'(c_{1t})\,c_{1t}-u'(c_2)\,c_2\right]=0$$

$$u'(c_{1t})\geq u'(c_2)\,.$$

Using the implementability condition we obtain a simpler definition of equilibrium. For initial portfolios $I_0$ given, an allocation $\{c_{1t},c_{2t},n_{1t},n_{2t}\}_{t=0}^{\infty}$ is a **competitive equilibrium with bank bailouts, taxes and default** if, and only if, it satisfies the conditions (8), (9) and (13).

## 3. Solution of The Ramsey Problem

Governments problem is to choose $\{e_0,\delta_0,\delta_0^*\}$ and $\{c_{1t},c_{2t},n_{1t},n_{2t},M_t\}_{t=0}^{\infty}$ in order to maximize (3) subject to conditions (8), (9) and (13), with initial portfolios $I_0$ given. Conditions (8), (9) and (13) insure that the chosen allocation is a competitive equilibrium. The taxes and exchange rates that implement each allocation are given by (11).

We will focus on the case where all bonds at $t=-1$ are issued by the government and all private agents have initial positive bond holdings—i.e.

$$B_{-1}^H,B_{-1}^B,-B_{-1}^G,B_{-1}^{*H},B_{-1}^{*B},B_{-1}^{*F},-B_{-1}^{*G}>0.$$

Note that consumption of the credit good must be constant over time, so the government can only choose the level of the tax, but must keep it constant[3]. On the other hand,

[3]This is due to the fact that this is a small open economy so the real interet rate is constant and because leisure entres linearly in the utility function. Thus, if taxes were not the same in two consecutive periods, the

the government can choose different values for consumption of the cash good over time by changing the devaluation rate constrained to satisfy the non-negativity of nominal interest rates. Finally, the government also chooses the initial nominal exchange rates and default rates. Government chooses $\{c_{1t}, n_{1t}, n_{2t}\}_{t=0}^{\infty}$ and $\{c_{2}, e_0, \delta_0, \delta_0^*\}$ to maximize the Lagrangian

$$
\begin{aligned}
\mathcal{L} \;\; = \;\; & \sum \beta^t \left[ U(c_{1t}) + U(c_2) - \alpha(n_{1t} + n_{2t}) \right] \\
& -\lambda \left[ u'(c_2) \left[ (1-\beta) a_0^H + g \right] + (1-\beta) \sum_{t=0}^{t} \beta^t \left[ \alpha n_t - u'(c_{1t}) c_{1t} - u'(c_2) c_2 \right] \right] \\
& - \sum \beta^t \gamma_t [c_{1t} - n_{1t}] - \omega[\sum \beta^t (c_{2t} - n_{2t}) - (1-\delta_0^*) B_{-1}^*] \\
& -\mu_0 [0 - \delta_0] - \mu_1 [\delta_0 - 1] - \mu_0^* [0 - \delta_0^*] - \mu_1^* [\delta_0^* - 1]
\end{aligned}
$$

We ignore the non-negativity constraints on nominal interest rates and later verify that they will be satisfied.

First, we discuss the necessary conditions for an interior optimum with respect to consumption and labor. To simplify the discussion and focus on the optimal choices of default rates and devaluation rates, consider the case in which $U(c) = c^{1-\sigma}/(1-\sigma)$. These first order conditions can be combined to yield

$$
(14) \quad U'(c_{1t}) = \frac{[1 + \lambda(1-\beta)]}{[1 + \lambda(1-\beta)(1-\sigma)]}
$$

domestic real interest rate would be different from the foreign and capital inflows would be unbounded.

and

$$(15)\quad U'(c_2) - \lambda U''(c_2)(1-\beta)\left[(1-\beta)\,a_0^H + g\right] = \frac{[1+\lambda(1-\beta)]}{[1+\lambda(1-\beta)(1-\sigma)]}$$

First, note that (14) implies that the optimal nominal interest rate is constant over time, so in the solution $c_{1t} = c_1$ for all $t$. Also, combining (14) and (15) we obtain

$$U'(c_2) - \frac{\lambda U''(c_2)(1-\beta)\left[(1-\beta)\,a_0^H + g\right]}{[1+\lambda(1-\beta)(1-\sigma)]} = U'(c_1)$$

Note also that the multiplier $\lambda$ is positive, since it measures the marginal cost of increasing the transfers $g$. Thus, $U'(c_2) < U'(c_1)$, which means that $\left(1+\left(1-\frac{e_t}{e_{t+1}}\right)\right) > 1$, or $1 > \frac{e_t}{e_{t+1}}$. Thus, the optimal policy is characterized by a positive and constant devaluation rate[4]. These results are standard in the literature on dynamic Ramsey problems.

We now focus on the optimal choice of devaluation and default rates at time zero in en economy with bank bailouts.

Using bank's balance sheets at $t=-1$, and assuming $i_{-1} = i^*_{-1} = 0$, $e_{-1} = 1$, bank

[4] In this economy, Friedman rule fails to be optimal, since the value of the goverenmnt liabilities depends on the value of consumption of the credit good at time one - note that this is the source of time inconsistency in Lucas and Stokey (1983). If this were a close economy, this effect would change the relative price betwen the cash and the credit good only at time zero, and Friedman rule would be optimal form time one on. However, in this open economy model the value of credit good consumption must be constant over time, thus, this effect distorts the relative price between cash and credit gods at every period.

bailouts can be written as[5]

$$\begin{aligned}\frac{T(\delta_0,\delta_0^*,e_0)}{e_0} &= \max\left\{\left(1-\frac{1}{e_0}\right)\left(B_{-1}^B+L_{-1}-D_{-1}\right)+\delta_0\frac{B_{-1}^B}{e_0}+\delta_0^* B_{-1}^{B*},0\right\}\\ &= \max\left\{\left(1-\frac{1}{e_0}\right)\left(D_{-1}^*-B_{-1}^{B*}-L_{-1}^*\right)+\delta_0\frac{B_{-1}^B}{e_0}+\delta_0^* B_{-1}^{B*},0\right\}.\end{aligned}$$

Changes in exchange rates and default on bonds held by banks may trigger bailouts. The relation between bailouts and exchange rates depends on the currency exposure of banks, as shown by the expression

$$\frac{\partial\frac{T(\delta_0,\delta_0^*,e_0)}{e_0}}{\partial e_0}=\frac{(1-\delta_0)\,B_{-1}^B+L_{-1}-D_{-1}}{e_0^2}$$

The size of bank bailouts is an increasing function of devaluations when banks have positive net assets denominated in domestic currency. If banks have net liabilities in domestic currency devaluations contribute to ex-post bank profits and reduce the size of bailouts. If there is no default on domestic currency bonds, bank's domestic currency exposure is equal to $D_{-1}^*-B_{-1}^{B*}-L_{-1}^*$. Bailouts are an increasing function of the exchange rate when there is liability dollarization—$D_{-1}^*>B_{-1}^{B*}+L_{-1}^*$. When there is a currency mismatch in banks portfolios, we will say that there is liability dollarization when $(1-\delta_0)\,B_{-1}^B+L_{-1}>D_{-1}$.

5

$$\begin{aligned}T_0 &= \frac{D_{-1}-(1-\delta_0)\,B_{-1}^B-L_{-1}}{e_0}+\left(D_{-1}^*-(1-\delta_0^*)\,B_{-1}^{B*}-L_{-1}^*\right)\\ &= \frac{D_{-1}-B_{-1}^B-L_{-1}}{e_{-1}}\left(1-\left(1-\frac{e_{-1}}{e_0}\right)\right)+\left(D_{-1}^*-B_{-1}^{B*}-L_{-1}^*\right)\\ &\quad+\delta_0^*B_{-1}^{B*}+\delta_0\frac{B_{-1}^B}{e_0}\\ &= \frac{B_{-1}^B+L_{-1}-D_{-1}}{e_{-1}}\left(1-\frac{e_{-1}}{e_0}\right)+\delta_0^*B_{-1}^{B*}+\delta_0\frac{B_{-1}^B}{e_0}\end{aligned}$$

Depending on whether there is liability dollarization or not, bail outs are positive or negative depending on whether $e_0 \gtrless \bar{e}_0$.

$$\begin{aligned} \text{If } (1-\delta_0) B_{-1}^{B} + L_{-1} - D_{-1} &> 0 : T(\delta_0, \delta_0^*, e_0) > 0 \Leftrightarrow e_0 > \bar{e}_0 \\ \text{If } (1-\delta_0) B_{-1}^{B} + L_{-1} - D_{-1} &< 0 : T(\delta_0, \delta_0^*, e_0) > 0 \Leftrightarrow e_0 < \bar{e}_0 \end{aligned}$$

where

$$\bar{e}_0 = \frac{(1-\delta_0) B_{-1}^{B} + L_{-1} - D_{-1}}{\left(B_{-1}^{B} + L_{-1} - D_{-1}\right) + \delta_0^* B_{-1}^{B*}}.$$

It will be useful to have expressions for private assets with and without bailouts. If there is no bailout private assets are

$$a_0 = \frac{M_{-1} + (1-\delta_0)\left(B_{-1}^{H} + B_{-1}^{B}\right)}{e_0} + (1-\delta_0^*)\left(B_{-1}^{H*} + B_{-1}^{B*}\right),$$

while in the case where there is a bailout they are

$$\begin{aligned} \bar{a}_0 &= \frac{M_{-1} + (1-\delta_0) B_{-1}^{H} + D_{-1} - L_{-1}}{e_0} + (1-\delta_0^*) B_{-1}^{H*} \\ &\quad + B_{-1}^{B*} + B_{-1}^{B} + L_{-1} - D_{-1}. \end{aligned}$$

Consider now the fist order conditions of the Ramsey problem with respect to $\delta_0^*$

$$(16) \quad -\lambda U'(c_2)(1-\beta)\frac{\partial a_0^H}{\partial \delta_0^*} - \omega B_{-1}^* = \mu_1^* - \mu_0^*$$

and

$$\begin{aligned} \frac{\partial a_0^H}{\partial \delta_0^*} &= -\left(B_{-1}^{H*} + B_{-1}^{B*}\right) \text{ with no bailout} \\ \frac{\partial \bar{a}_0^H}{\partial \delta_0^*} &= -B_{-1}^{H*} \quad \text{with bailout} \end{aligned}$$

Thus, under the assumption $B_{-1}^{H*}, B_{-1}^{B*} > 0$ in either case the derivative is negative. As, we also assume that initially the country is a net debtor (i.e., $B_{-1}^{F*} > 0$ ) the left-hand-side of (16) is positive and, since the multipliers ought to be nonnegative, then $\mu_1^* > \mu_0^* = 0$, which means that $\delta_0^* = 1$ is optimal. The intuition is very simple. Even though it is true that by defaulting on foreign currency denominated bonds the government can increase the contingent liabilities since banks can be holding some of those bonds, the net effect is positive, to the extent that households and foreigners hold positive amounts of foreign currency denominated debt.

Now, let us focus on the joint choices of $e_0$ and $\delta_0$. Note that the derivative of the Lagrangian with respect to $\delta_0$ is given by

$$-\lambda U'(c_2)(1-\beta)\frac{\partial a_0^H}{\partial \delta_0} = \mu_1 - \mu_0$$

where

$$\begin{aligned} \frac{\partial a_0^H}{\partial \delta_0} &= -\frac{B_{-1}^H + B_{-1}^B}{e_0} \text{ with no bailout} \\ \frac{\partial \bar{a}_0^H}{\partial \delta_0} &= -\frac{B_{-1}^H}{e_0} \text{ with bailout.} \end{aligned}$$

Under our assumptions on initial portfolios, as long as $e_0$ is bounded in both cases $\mu_1 > \mu_0 = 0$

and it is optimal to set $\delta_0 = 1$. Note, however, that in the case in which $e_0$ is arbitrarily large, the value of $\delta_0$ is inessential. As there is no benefit from defaulting we will assume that government chooses $\delta_0 = 0$ when $e_0$ is arbitrarily large.

The first order condition with respect to $e_0$ is

$$-\lambda U'(c_2)(1-\beta)\frac{\partial a_0^H}{\partial e_0}$$

where

$$\begin{aligned}
\frac{\partial a_0^H}{\partial e_0} &= -\frac{1}{e_0^2}\left[M_{-1} + (1-\delta_0)\left(B_{-1}^H + B_{-1}^B\right)\right] \text{ with no bailout} \\
\frac{\partial \bar{a}_0^H}{\partial e_0} &= -\frac{1}{e_0^2}\left[M_{-1} + D_{-1} + (1-\delta_0)\, B_{-1}^H - L_{-1}\right] \text{ with bailout}
\end{aligned}$$

The optimal choice of the initial exchange rate depends crucially on the interaction between private balance sheet positions and bailouts.

If $(1-\delta_0)\, B_{-1}^B + L_{-1} < D_{-1}$ bailouts are a decreasing function of the exchange rate and become zero for $e_0 > \bar{e}_0$. In this case, for a large enough exchange rate there is no bailout because banks are net debtors in domestic currency and for a large enough $e_0$ ex-post bank profits will be non-negative. As $M_{-1} + (1-\delta_0)\left(B_{-1}^H + B_{-1}^B\right) > 0$ it is optimal to set $e_0$ as large as possible. The devaluation removes the incentives to set $\delta_0 = 1$ since it makes the real value of the domestic currency government debt equal to zero. $\delta_0 = 0$.

If there is liability dollarization in the banking system. $(1-\delta_0)\, B_{-1}^B + L_{-1} > D_{-1}$, bailouts are an increasing function of the exchange rate and are positive for $e_0 > \bar{e}_0$. The optimal choice of $e_0$ in this case depends on whether $M_{-1} + (1-\delta_0) B_{-1}^H \lesseqgtr L_{-1} - D_{-1}$.

If $M_{-1} + (1-\delta_0)B^H_{-1} > L_{-1} - D_{-1}$, it is optimal to increase the nominal exchange rate without bound. Note that this expression will be positive when the gains from devaluing, given by $M_{-1} + (1-\delta_0)B^H_{-1}$, exceeds the bail-out required to keep the banking sector from going bankrupt, given by the net domestic currency denominated assets in the banking sector, $L_{-1} - D_{-1}$. In this case, the net fiscal effect of a devaluation is positive. As we mentioned before, in this case there is no point in using the instrument $\delta_0$ so we set $\delta_0 = 0$.

If $M_{-1} + (1-\delta_0)B^H_{-1} < L_{-1} - D_{-1}$ and there is liability dollarization the optimal exchange rate is $e_0 = \bar{e}_0$. For $e_0 < \bar{e}_0$ there is no bailout so $\partial a^H_0 / \partial e_0 > 0$. For $e_0 > \bar{e}_0$ there is a bailout and $\partial a^H_0 / \partial e_0 < 0$. The intuition for this result is that if there is no bailout the government levies a lump-sum tax by devaluing. If there is a bailout, the net fiscal effect of a devaluation in this case is negative. Furthermore, since the optimal $e_0$ is finite government will set $\delta_0 = 1$. As the government lowers $e_0$ (revalues) it improves bank profits, reducing transfers to banks. It will do so until the value of the transfers is zero. The gain from reducing bailouts exceeds the cost that arises from the increase in the real value of non-defaulted nominal government liabilities, $M_{-1}$. The value of $\bar{e}_0$ when $\delta_0 = \delta^*_0 = 1$ is lower than one. $\bar{e}_0 < 1$[6].

In summary, the government always defaults on foreign currency denominated liabilities. In addition, when a devaluation does not reduce the profits of domestic banks $\left(B^B_{-1} + L_{-1} < D_{-1}\right)$, the government will devalue. When the devaluation does reduce the profits of banks a bail out follows a devaluation. In this case, as the previous discussion argues, the optimal decisions with respect to either devaluing or defaulting on peso denomi-

[6]The fiscal effects of this revaluation are likely to be small, so in the numerical exercise of the next subsection we will ignore this effect and assume that in this case the governemnt does not change the nominal exchange rate.

nated bonds imply corner solutions. Thus, we can treat them as a binary decision problem. If the government defaults on domestic bonds, the gains are given by $B_{-1}^{B}$; while if the government devalues, the gains are given by $B_{-1}^{B} + M_{-1} - L_{-1} + D_{-1}$. The decision to devalue will be optimal when $B_{-1}^{B} < B_{-1}^{B} + M_{-1} - L_{-1} + D_{-1}$, or $0 < M_{-1} - L_{-1} + D_{-1}$.

The following table summarizes all the possible cases for the optimal choice of $e_0, \delta_0$, and $\delta_0^*$.

| | $\delta_0^*$ | $\delta_0$ | $e_0$ |
|---|---|---|---|
| $B_{-1}^{B} + L_{-1} < D_{-1}$ | 1 | 0 | $\infty$ |
| $B_{-1}^{B} + L_{-1} > D_{-1}$ and $M_{-1} > L_{-1} - D_{-1}$ | 1 | 0 | $\infty$ |
| $B_{-1}^{B} + L_{-1} > D_{-1}$ and $M_{-1} < L_{-1} - D_{-1}$ | 1 | 1 | $\bar{e}_0$ |

## 4. Application to Argentine Data: 1994-2001.

To evaluate which scenario is relevant for the Argentine case we use aggregated monthly data of government and private sector balance sheets covering the period 1994-2001.

### A. The data

The Central Bank (BCRA) publishes its Consolidated Financial Statements on a monthly basis since 1994 in the Boletín Estadístico. They are available and can be downloaded at the BCRA's website (http://www.bcra.gov.ar). Government debt data has been obtained from the Informe Económico and the Boletín Fiscal, both published by the Ministerio de Economía.

Most of the balance sheet variables appear in the BCRA publications. Others need to be constructed. The monetary circulation outside the financial system account was chosen to represent the monetary base variable (M) because the theoretical model does not allow for banks to have a money demand. Bank's money demand was treated as if banks were holding government bonds. Loans (L) was computed as peso denominated Credit to the Private Sector following the Central Bank's statistical bulletin (Boletín Estadístico). This account includes overdrafts, discounts, mortgage loans, pledge lending, personal loans, private securities and accrued resources on loans. These last two concepts were included because they do not differ significantly from the definition of loans in the theoretical model since the account Accrued Resources on Loans includes interest funds which were not paid but were agreed on at the time of taking the loan. This item accounted for almost 14.7% of the total in January 1994.

Deposits (D) are calculated as domestic currency Deposits made by the Private Sector, including current accounts, savings accounts and time deposits. Accrued Resources on Deposits were not included since they make no difference because they are less than 0.4 percent of total peso deposits.

Government bonds in banks' portfolios ($B^B$) were calculated as the sum of the account Credit to the Public Sector in domestic currency and monetary circulation in financial institutions net of deposits made by the public sector. Credit to the public sector includes loans to the national, provincial and municipal governments and to official entities, public securities and the Use of Unified Funds account. Accrued Resources on Loans are included since this item accounted for 22.3% of the total in January 1994. Deposits made by the public sector includes deposits of national, provincial and municipal governments and the same type of deposits included in D. The Accrued Resources on Deposits account was not included since it represented less than 0.17% of the total in January 1994. $B^B$ is negative in the first half of 1994 and then turns positive until December 1997 with two exceptions in January and May

1997. From January 1998 to the present $B^B$ is negative at all times.

We constructed the series

$$R_1 = D_{-1} - B^B_{-1} - L_{-1}$$

and

$$R_2 = M_{-1} + D_{-1} - L_{-1}.$$

The model predicts that if $R_1 \geq 0$, $D_{-1} \geq B^B_{-1} + L_{-1}$, then it is optimal to devalue, and that if $R_1 < 0$, a bail out to the banks follows a devaluation. When $R_2 > 0$ , the cost of the bail out is not too large, so a devaluation follows. If $R_2 < 0$, the bail out is larger than the gains from devaluing, which means that the government will never devalue.

The values for $R_1$ and $R_2$ when bank's currency positions are taken at face denomination are plotted in Figure 1. The value for $R_1$ is negative until the end of 1997. This means that there is no liability dollarization and a devaluation is optimal. Starting in 1998, $R_1$ becomes positive, which means that a bail out to the banks follows a devaluation. However, $R_2$ is positive, so the gains from devaluing outweigh the bail out so a devaluation is still optimal.

If this calculation were the appropriate one, the identification assumption would be that the default rate on peso denominated bonds is zero, so

$$i_t - r_t = E\left[\varepsilon_{t+1}\right]$$

$$i_t^* - r_t = E\left[\delta_{t+1}^*\right],$$

Figure 2, reports the interest rate differentials $i_t - r_t$, $i_t - i_t^*$ and $i_t^* - r_t$, as defined in the introduction. The standard interpretation is that $i_t - r_t$ is the total risk on an Argentinean bond, relative to a US bond. This total risk is typically decomposed into a sovereign risk $i_t^* - r_t$ and a devaluation risk $i_t - i_t^*$. The identifying restriction of our theoretical model coupled with the calculations of Figure 1 implies that $i_t - r_t$ represents devaluation risk while $i_t - i_t^*$ represents the difference between the devaluation risk and the sovereign risk. In this case, the standard interpretation severely underestimates the expected devaluation rate.

A problem with the computations presented in Figure 1 is that part of the assets of banks, although denominated in dollars, may represent liabilities of firms that would suffer substantially form a depreciation of the real exchange rate that could follow a nominal devaluation. As a first approximation to the problem, we did the calculations as if all dollar denominated non-collateralized loans of the banking sector were in pesos. Figure 3 depicts the results of this exercise. As it can be seen, the results change dramatically: $R_1$ becomes negative for the whole period, meaning that a bail out to the banks follows a devaluation. In addition, $R_2$ is also negative, meaning that the cost of the bail out is larger than the fiscal gain of the devaluation. Therefore, according to this interpretation, the government would never devalue.

If this calculations were right, the identifying assumption would be that the expected devaluation should be zero and that the expected default should be the same in both currencies. Thus, the correct formulas would be

$$i_t = i_t^*$$

$$i_t^* - E\left[\delta_{t+1}\right] = r_t,$$

Obviously, this identification hypothesis seems inconsistent with the data since we observed $i_t > i_t^*$.

An interpretation that we would prefer, though, is that the incentives to default on peso denominated assets via a devaluation or a direct default on bonds depends on the effective size of the bail out to the banking system and that it is hard to measure it ex-ante. Thus, the decision the government would take relative to peso denominated assets in the event of a default is seen by the market as a random variable. If this is indeed the case, then, expected default in peso denominated bonds is positive, but less than expected default on dollar denominated bonds. Then, $E\left[\varepsilon_{t+1}\right] > 0$,and $0 < E\left[\delta_{t+1}\right] < E\left[\delta_{t+1}^*\right]$ , so

$$E[\varepsilon_{t+1}] = i_t - i_t^* + E\left[\delta_{t+1}^*\right] - E\left[\delta_{t+1}\right] > i_t^* - i_t$$

$$E\left[\delta_{t+1}^*\right] = i_t^* - r_t,$$

Under this interpretation, the devaluation risk, measured by $i_t^* - i_t$ in Figure 2, underestimates the true devaluation risk but not as much as if $E\left[\delta_{t+1}\right] = 0$.

Finally, recall that in our analysis, when a devaluation is optimal, any value for $E\left[\delta_{t+1}\right]$ is a solution, so we set $E\left[\delta_{t+1}\right] = 0$. Note, however, that this decision is indeed important. In particular, had we chosen $E[\delta_{t+1}] = 1$, in the first case in which it was optimal to devalue, the real measure of the devaluation risk would have been $i_t^* - i_t$! So, our model above is consistent with the standard approach, but only as a knife edge, in the sense that any other value for the default rate is as good as that one.

These numerical exercises are clearly preliminary. The aim is to highlight the importance of the underlying identifying assumption typically made in the literature when decomposing interest rate differentials into different risk sources. Obtaining more precise estimates of the true default and devaluation risks, within the simple theoretical model sketched here, requires a much deeper numerical analysis. Moreover, considering alternative theoretical frameworks to incorporate other relevant features of emerging economies seems an obvious avenue for future research.

## 5. Concluding Remarks

A key issue in the discussion of the benefits of dollarization is the hypothesis that in economies where there is liability dollarization in the banking sector a devaluation will cause a default on sovereign debt. If this alleged causal relationship actually exists removing the technology to devalue will reduce sovereign risk with all the benefits that this entails. Testing whether this positive correlation between default risk and devaluation risk exists in the data is crucial when evaluating the benefits of dollarizing an economy. Uncovering this correlation in the data is difficult because expected defaults and expected devaluations are unobserved variables. The main problem in uncovering these default and expected devaluation rates is that the lack of peso denominate bonds issued by, say the US Treasury introduces an identification problem: we only have two arbitrage conditions to unravel the expected devaluation rate and the default rates on peso and dollar denominated bonds issued by the Argentinean government.

In order to solve for this identification problem, we propose an off the shelve model of government behavior. We solve a simple dynamic model of a small open economy with fixed exchange rates where the government bails out banks with negative profits and chooses devaluation and default rates on domestic and foreign currency to interpret the data.

The model is very simple and as such has many limitations, discussed in more detail in the paper. Its purpose is to highlight the identification problem and how government choices affect the interpretation of interest rates differentials. Some obvious weaknesses of the model are that we take initial balance sheet positions and the willingness of governments to bail out banks as given. In the identification exercise, we also ignore the possibility that for some reason not captured in the model, the government may have to default[7]. The model is also completely silent with respect to the virtues of dollarization. It predicts that in economies where liabilities are dollarized governments will never chose to devalue. It suggests that the case for dollarization is strong when for some reason outside our model the government devalues even though that is not the optimal policy.

An application to Argentina during the period 1994-2001 provides mixed results, depending on the interpretation of banks balance sheets. When these are taken at face value, the data suggests that in case of a default, a devaluation is preferred to a default on peso denominated bonds. However, when balance sheets are adjusted so that bank's non-secured dollar denominated loans are considered as if they were in pesos, the results change. In this

[7] Some plausible reasons are a run on banks couples with a run on the central bank's reserves, or a fiscal shock coupled with a lack of access to the credit markets that forces the government to use the reserves to pay for that fiscal shock.

scenario, a devaluation is never optimal because it triggers a bank bailout that is costlier than the fiscal gains of the devaluation.

Our own interpretation is that given this mixed results, the decision to devalue or default, in case of crisis, must be seen as a random variable by the market. In this case, the standard way to measure devaluation risk underestimates the true risk. Under this interpretation, the literature that discusses the empirical relationship between default and devaluation risk may be misleading.

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**Figure 1: Balance Sheet Positions**

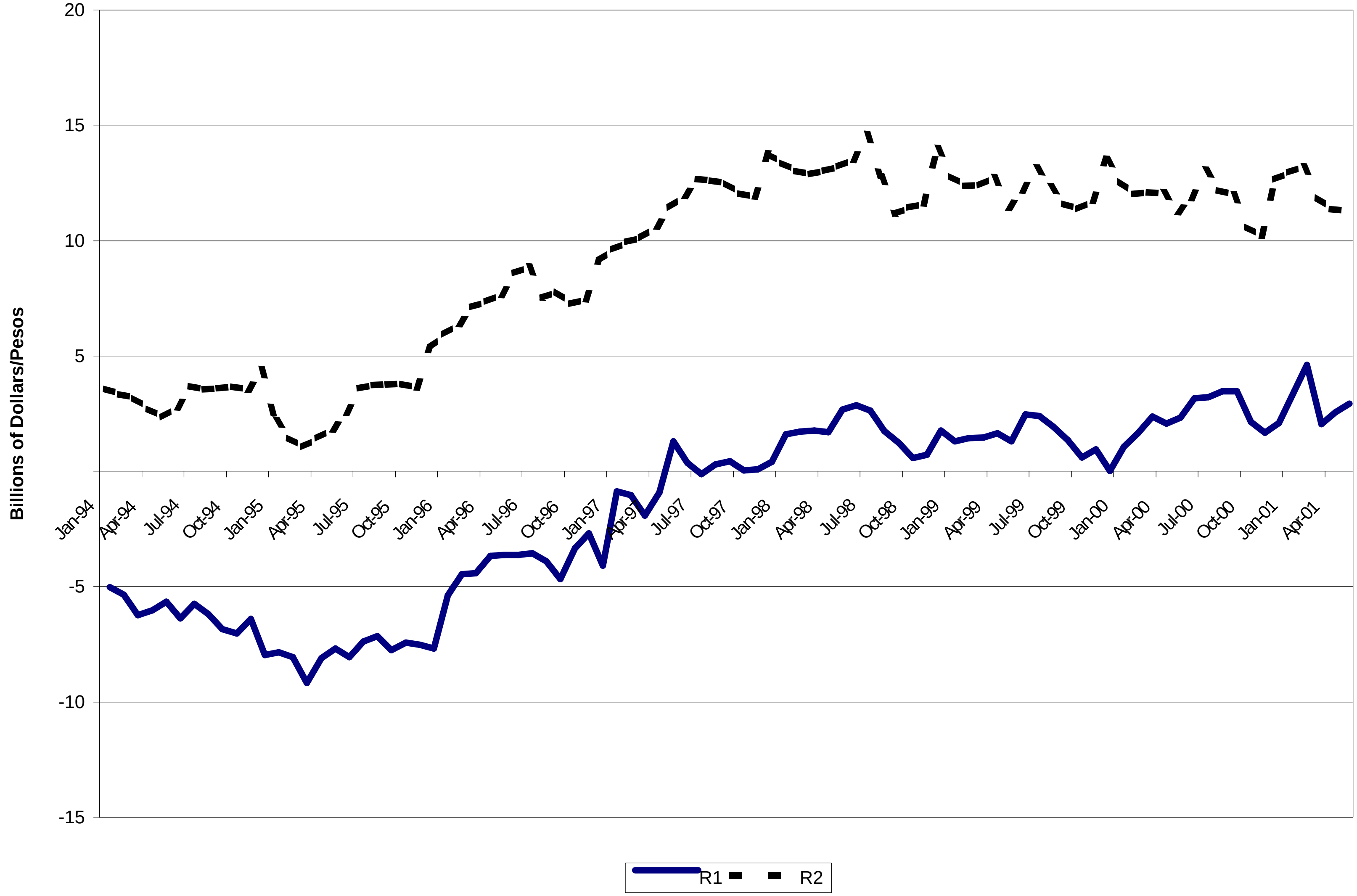

**Figure 2: Interest Rate Differentials**

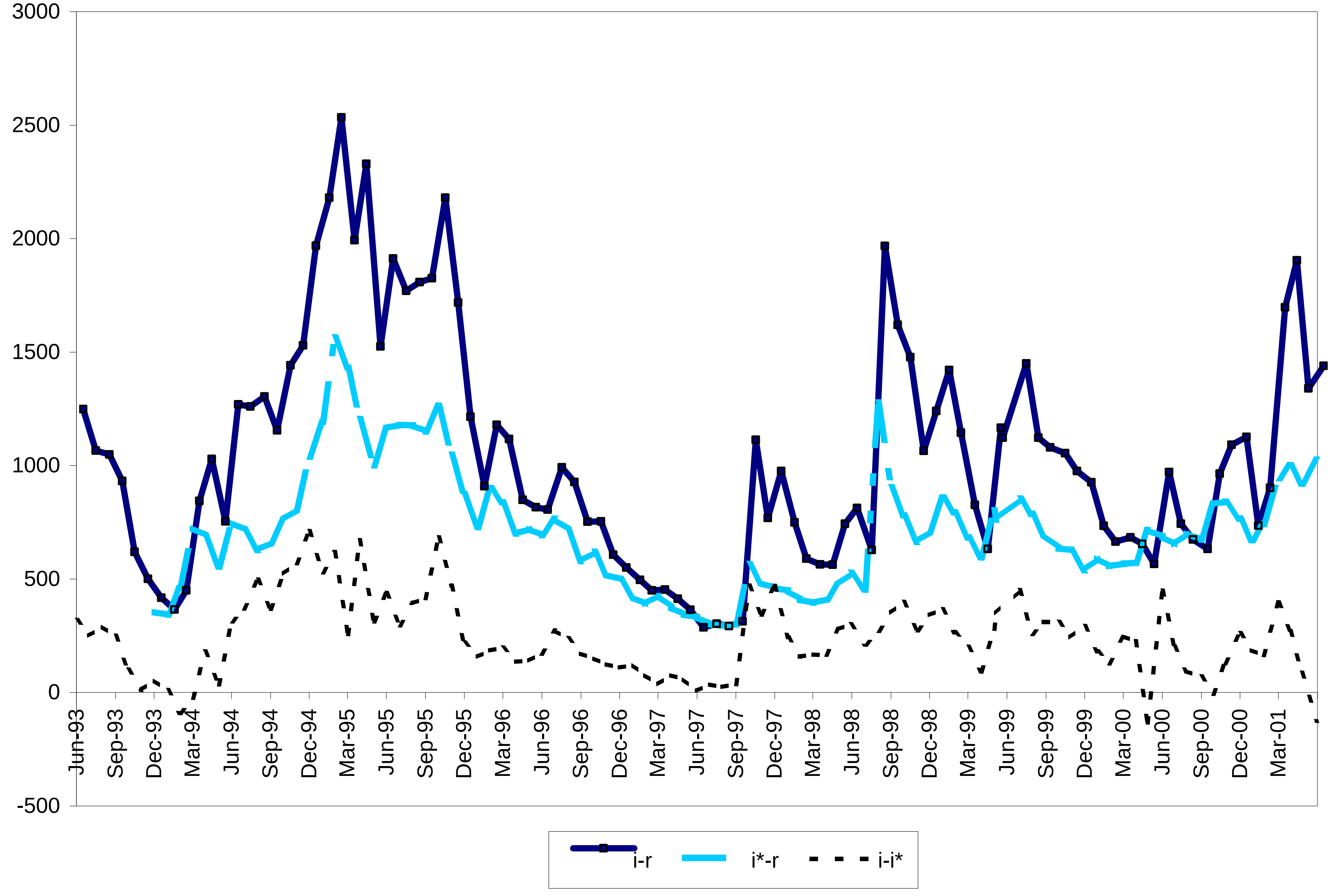

**Figure 3: Adjusted Balance Sheet Positions**
**(All Non-secured loans of Banks interpreted as peso loans)**