QUAERERE VERUM

UNIVERSIDAD DE SAN ANDRÉS

Seminario del Departamento de Economía

"Exchange rate based inflation stabilization with a currency board"

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Martes 13 de octubre de 1998
11 hs.
Aula Chica de Planta Baja

EXCHANGE RATE BASED INFLATION STABILIZATION WITH A CURRENCY BOARD

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Preliminary. Comments welcome.

This version: September 22, 1998.

Abstract:

This paper develops a two-period stochastic model of an exchange rate based inflation stabilization plan with a currency board. It considers a dynamic game framework in which inflation and the levels of fiscal expenditure and public debt determine the payoffs available to the policymaker at each period of the game. A tax revenue shock threatens the sustainability of the currency board and the credibility of the fixed exchange rate regime. This shock will be more damaging the larger are the fiscal expenditure demands and the inherited public debt stocks, and the higher the domestic and international interest rates and devaluation expectations. Hence, the policymaker must face a fundamental trade-off between the credibility and flexibility of such regimes. Some interesting implications about the fiscal expenditure policy and the management of the currency composition of public debt are drawn from the model.

JEL Classification Numbers: E5, E6.

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Este trabajo desarrolla un modelo estocástico de dos períodos de un plan de estabilización de la inflación basado en el tipo de cambio y con una caja de conversión. Considera un esquema de un juego dinámico en el cual la tasa de inflación y los niveles de gasto y deuda pública determinan los pagos disponibles al hacedor de política en cada período del juego. Un shock en la recaudación impositiva amenaza la sostenibilidad de la caja de conversión y de la credibilidad del régimen de tipo de cambio fijo. Este shock será más perjudicial cuanto mayores sean las demandas sobre el gasto público y los stocks de deuda pública en ambas monedas, y más altas sean las tasas de interés doméstica e internacional y las expectativas de devaluación. En consecuencia, el hacedor de política debe enfrentar un compromiso fundamental entre la credibilidad y la flexibilidad de tales regímenes. Del modelo pueden extraerse algunas implicaciones interesantes acerca de la política del gasto público y de la administración de la composición en diferentes monedas de la deuda pública.

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1- Introduction

High inflation and hyperinflation are invariably characterized by a great disorder in public finances[1]. In such episodes, the government becomes unable to cope with expenditure demands, and must rely on seigniorage revenues (an inflation tax "paid" by the majority of society), because of a limited taxation capacity. These expenditures may either come from demands for public goods by consumers, demands for subsidies from lobbying interest groups or represent essential social expenditure that cannot be easily reduced without facing considerable political costs[2]. The discrepancy between the level of such expenditures and limited tax revenues defines the fiscal pressure.

The question that then arises is about the implications of this fiscal pressure when the government implements an exchange rate based inflation stabilization plan with complete internal convertibility such as through an orthodox currency board[3], which, by definition, excludes an inflation tax as a discretionary revenue instrument.

Following the mainstream exchange rate policy game literature, our contribution consists of addressing this question by incorporating this fiscal pressure in the policymaker's preferences as an argument that threatens the sustainability of the currency board and the credibility of the fixed exchange rate regime. Another key feature in our model is the fact that private sector agents know the optimization problem faced by the policymaker. Thus, the interactions between the policymaker and the private sector are captured by modeling both the probability and the size of the discretionary devaluation as an endogenous variable.

The stochastic game setup developed below not only emphasizes the policymaker's fundamental trade-off between credibility and flexibility within the currency board and fixed exchange rate regimes, but also combines two opposing effects that influence the evolution of this trade-off during the game. In particular, the model considers the positive effect on credibility of maintaining internal currency convertibility and the fixed exchange rate, but also the negative effect that a persistent fiscal pressure has on the sustainability and hence also the credibility of such regimes, via public debt accumulation.

The remainder of the paper is organized as follows. Section 2 briefly overviews the main concepts and the policy issues to be analyzed. Section 3.1 sets out the basic model of a two-period stochastic policy game with explicit fiscal pressure. Sections 3.2 and 3.3 present the second period Nash solution and the first period Stackelberg solution, respectively. The Nash solution is obtained taking devaluation expectations as given, while the Stackelberg solution considers the effects of the first period's policies on the second period devaluation expectations. Section 4 concludes with the interpretation of the results and some policy implications.

2- Main concepts and policy issues

As in Greene and Isard(1991), **internal currency convertibility** is the legal right of **residents** to acquire, maintain, and transact domestic holdings of foreign currency assets without differential taxes and subsidies. It is the convertibility of currency between residents within national borders while **external currency convertibility** is related to transactions **between residents and nonresidents**. There are also degrees in internal currency convertibility. We will always refer to **complete internal currency convertibility**, meaning the freedom for residents to use their domestic holdings of foreign currency to make both current and capital transactions domestically.

An **orthodox currency board** is an independent currency authority arrangement by which the domestic currency exchange rate against the foreign currency is **fixed permanently** and the foreign reserve backing is 100 percent. Its main benefits are promoting price stability and convertibility and simplifying central bank operations. At the same time, it constrains the policymaker's discretion on fiscal and monetary policy more than conventional fixed exchange rate regimes.

Moreover, fiscal policy plays a crucial role within an orthodox currency board regime. On the one hand, inflation tax revenues are limited to those implied by foreign inflation and the only remaining seigniorage revenue comes from the difference between the interest earnings from the investment of foreign reserves and the administrative and operational expenses of the currency board. On the other hand, solvency requires an intertemporal fiscal surplus equivalent to interest and net debt payments and so, only limited and transitory deficits are allowed.

In an orthodox currency board regime, the base money is determined solely by the evolution of foreign exchange reserves. The Central Bank's functions are limited to the management of the currency board and the supervision of the financial system. Hence, apart from changes in reserve requirements that affect the base money multiplier and some limited open-market operations, money supply is then completely determined by the balance of payments result and the financial intermediaries, and is therefore out of the policymaker's control. For this reason, the behavior of monetary policy will be disregarded as an active policy instrument in our model.

In this context, the **sustainability** of complete internal convertibility as through an orthodox currency board and the **credibility** of the fixed exchange rate regime, given the fiscal pressure and possibly adverse shocks, become the critical policy issues.

The precommitments on the currency board and the fixed exchange rate are aimed at stabilizing inflation and devaluation expectations and at producing a rapid disinflation with minimal loss in terms of forgone output and employment. The tying of his hands in this way, represents an attempt to ensure the policymaker's credibility with regard to the implementation of policy announcements and the general policy strategy. We will refer to **credibility** as the likelihood estimated by the private sector that the policy commitments will be maintained even in the presence of adverse shocks[4].

The **sustainability** of fixed exchange rate regimes has been addressed in the literature by two classes or "generations" of **speculative attack and balance of payments crises models**[5]. The first of these analyze the consequences of incompatible fiscal, monetary and exchange rate policies for the balance of payments of a small open economy. In a seminal paper, Krugman(1979) showed that, under a fixed exchange rate regime, an expansionary monetary policy leads to a gradual loss of foreign exchange reserves and, finally, to a speculative attack against the domestic currency that forces the abandonment of the fixed exchange rate regime. Because of the nonlinearities involved in his model, however, Krugman was unable to derive explicitly a solution for the timing of the collapse of the fixed exchange regime. Later work by Flood and Garber(1984a) provided an example with a solution in a linear model.

Subsequent literature[6] has amended and extended these original models by incorporating several topics: the nature of the post collapse exchange rate regime, uncertainty regarding the monetary policy rule and the critical level of reserves that triggers the regime switch, real effects of anticipated crises, external borrowing and capital controls, imperfect asset substitutability, sticky prices and endogenous policy switches to avoid the collapse.

The structure of these models implies that the only possible equilibrium is that of devaluation. A second class of model, which began with Flood and Garber(1984b) and Obstfeld(1986), allows for multiple equilibria in the foreign exchange market. Many of these models are called **"models of self-fulfilling speculative attacks"**[7], because the speculators' views, rather than the incompatibility of the policy stance, *causes* the currency devaluation even within an ex-ante viable and sustainable fixed exchange rate regime. Another important difference between these two classes of model is that the second class incorporates explicitly the optimizing behavior of the policymaker.

The **credibility** of a fixed exchange rate regime in the absence of a binding commitment technology has been extensively analyzed in the literature using a game theoretic framework[8]. In general, the policymaker may decide to switch from a fixed exchange rate regime to a flexible one and so reneging on his promises, if the benefits of doing so offset the costs. Hence, the policymaker's political incentives and constraints rather than the loss of foreign exchange reserves *cause* the switch from one exchange rate regime to another. The paradigm here is the monetary policy game in a closed economy developed by Kydland and Prescott(1977), Barro and Gordon(1983) and Barro(1986), adapted to the open economy[9].

More recently, models developed by Drazen and Masson(1994), Masson(1995), Masson and Agénor(1996) and Velasco(1996a), consider a broader concept of credibility that also includes the costs of sticking to his announced policy rules. They ask whether maintaining fixed exchange rates, in the presence of adverse shocks and state variables (persistent unemployment, debt accumulation), increases or decreases credibility and hence whether this lowers or enhances devaluation expectations. However, in none of these models, are the probability and the size of discretionary devaluation both jointly endogeneized.

Literature (Chen(1995), Rose and Asea(1996), Velasco(1996b), Velis(1997)) is now oriented towards developing models linking both speculative activity and policymaking within an optimizing framework, by considering the economic decisions of private agents in the currency markets and those of the policymaker.

The fiscal pressure in an exchange rate policy game can be subject to a closer analysis. Several aspects are especially relevant in the context of an exchange rate based inflation stabilization plan with an orthodox currency board given an outstanding fiscal pressure:

1) The joint analysis of alternative policy instruments (See Agell et al.(1994), as a first attempt in this direction), instead of focusing solely on the nominal exchange rate, as in most models.

2) The role played by the currency composition of public debt on the sustainability of the currency board and the credibility of the fixed exchange rate regime.

In the model that follows we attempt to address both of these issues. In particular, we analyze the role played by the fiscal expenditure in nontradables and the level and currency composition of public debt within an orthodox currency board regime. Also, expectations of a regime switch are built into the game setup and thus influence the policymaker's and the private sector's decisions. As a result of this, the probability and the size of discretionary devaluation are both derived as endogenous variables.

3- An exchange rate based inflation stabilization policy game with a currency board

3.1- The game and macroeconomic model structure

As in other public finance models[10], the government has to deal with a two-fold problem. On the one hand, the government is pressured by the need to supply public goods and social transfers to consumers and by the demand for subsidies from lobbying interest groups, which they are unable to finance by regular taxation[11]. On the other hand, finance by borrowing[12], cannot increase unboundedly without provoking an adverse reaction in the capital markets, or exceed an upper limit enforced by a multilateral commitment such as the Maastricht Treaty for European countries or the adjustment program goals for countries that subscribe financial agreements with the IMF. The policymaker's objectives therefore turn on the differential between domestic and international inflation rates and the gap between the actual and a "desired" level of fiscal expenditure in nontradables.

We consider a small open economy producing both tradable and nontradable goods in which fiscal and exchange rate policies are located within a single policymaker[13]. His instruments are the exchange rate[14], the level of fiscal expenditure in nontradables and the foreign currency public debt stock. In each period of the game, he must decide not just whether to devalue or not, but also how much to spend on nontradables and how much to borrow in foreign currency.

The policymaker then sets his instruments to minimize a loss function L_G (assumed to be convex and differentiable):

$$\underset{\{\pi, g^N, b^*\}_{t=1}^{2}}{Min} \; L_G = \delta^{t-1}\, \mathrm{E} \left\{ \tfrac{1}{2} \sum_{t=1}^{2} \left[\left(\hat{p}_t - \hat{p}_t^*\right)^2 + \alpha (g_t^N - \bar{g})^2 \right] + c_t \right\} \tag{3.1}$$

subject to,

$$g_t^N + (1+r_t)(1+\hat{p}_t^e - \hat{p}_t) b_{t-1} + e_t G_t^* - (\bar{t} + u_t) = b_t + e_t b_t^* \le \bar{b}_t \tag{3.2}$$

where,

$$r_t \cong i_t - \hat{p}_t^e = i_t^* + \tau_t \tag{3.3}$$

$$\hat{p}_t = \lambda(\pi_t + \hat{p}_t^*) + (1-\lambda)\hat{p}_t^N \qquad 0 < \lambda < 1 \tag{3.4}$$

$$\hat{p}_t^N = \pi_t^e + \hat{p}_t^{N-} \tag{3.5}$$

$$\hat{p}_t^{N-} = \left(P_t^N - E_t\right)^- - \left(P_{t-1}^N - E_{t-1}\right) \tag{3.6}$$

$$\hat{p}_t^e = E\hat{p}_t = \pi_t^e + \lambda \hat{p}_t^{*e} + (1-\lambda) E\hat{p}_t^{N-} \tag{3.7}$$

$$e_t = e_{t-1} + \pi_t + \hat{p}_t^* - \hat{p}_t \qquad e_0 = \bar{e}_0 \tag{3.8}$$

$$G_t^* = g^* + (1+r_t^*)(1+\hat{p}_t^{*e} - \hat{p}_t^*) b_{t-1}^* \tag{3.9}$$

where: $\hat{p}$: domestic inflation rate, $\hat{p}^*$: international inflation rate, g^N: real fiscal expenditure in nontradables, $\bar{g}$: "desired" fiscal expenditure in nontradables, π: actual devaluation rate, b*: foreign currency public debt stock at the end of period, δ: policymaker's discount factor ($0 < \delta < 1$), c_t: escape clause cost ($c_t > 0$ if devaluation occurs, $c_t = 0$, otherwise), r: real domestic interest rate, $\hat{p}^e$: expected domestic inflation rate, b: domestic currency public debt stock, e: real exchange rate, g*: real fiscal expenditure in tradables, r*: real international interest rate, $\hat{p}^{*e}$: expected international inflation rate, $\bar{t}$: real tax revenue in normal times, u: tax revenue shock (assumed to be uniformly distributed : $u_t \sim \text{iid}\left[-\bar{u}, \bar{u}\right]$, $E(u_t) = 0$, $\sigma_u^2 = \frac{\bar{u}^2}{3}$), $\bar{b}$: public debt limit in both currencies, i: nominal domestic interest rate, i*: nominal international interest rate, τ: financial risk premium, $\hat{p}_t^N$: nontradables' price variation, π^e: expected devaluation rate, $\hat{p}_t^{N-}$: target nontradables' price variation, P^N: nontradables' price index, E: nominal exchange rate. Finally, α

is a preference parameter of the policymaker that trades off the benefit from accommodating the fiscal pressure through devaluation with the cost of a non zero inflation rate. **All parameters and the probability distribution of the tax revenue shock are assumed to be common knowledge.**

In particular, a surprise devaluation may cause an unexpected reduction in the value of interest bearing, non-indexed, domestic currency public bonds, given that this feature of the debt is considered here as exogenous. Governed by the objectives of the policymaker, this "devaluation revenue" could be directed towards financing a larger fiscal expenditure in nontradables given the target level $\overline{g}$, rather than towards reducing the public debt stock.

To evaluate the cost associated with using devaluation we simply assume that the policymaker faces a fixed escape clause cost $c_t > 0$ whenever he devalues[15] during the stabilization plan. This cost is not necessarily proportional to the devaluation size or any other macroeconomic variable but can be associated with voter disapproval (when price stability is a central issue in the electoral process[16]) or even removal from office for the policymaker.

The setup is a two-period stochastic game, in which the domestic currency public debt stock is the state variable that links payoffs in both periods and influences devaluation expectations. Then, as repudiation is explicitly excluded in this model as a possible means of reducing the outstanding public debt, it becomes crucial that tax revenue shocks and policies have persistent effects on public debt accumulation in the model that extend to future periods, constraining the policies to be implemented in these periods.

To solve the game we will work on the following reduced form equations:

$$\hat{p}_t = \lambda\left(\pi_t - \hat{p}_t^*\right) + (1-\lambda)\left(\pi_t^e + \hat{p}_t^{N-}\right) \tag{3.10}$$

$$g_t^N + D_t - u_t - \left[e_{t-1} - (1-\lambda)\left(\hat{p}_t^{N-} - \hat{p}_t^*\right)\right]b_t^* - \left[B_t^d + (1-\lambda)b_t^*\right]\left(\pi_t - \pi_t^e\right) = b_t \le \overline{b}_t \tag{3.11}$$

where,

$$D_t = (1+r_t)\left[1 - \lambda\left(\hat{p}_t^* - \hat{p}_t^{*e}\right) - (1-\lambda)\left(\hat{p}_t^{N-} - E\hat{p}_t^{N-}\right)\right]b_{t-1} + \left[e_{t-1} - (1-\lambda)\left(\hat{p}_t^{N-} - \hat{p}_t^*\right)\right]G_t^* - \bar{t} \tag{3.12}$$

$$B_t^d = (1+r_t)\lambda b_{t-1} - (1-\lambda)G_t^* \tag{3.13}$$

$$\overline{g} > \overline{b}_t - D_t + u_t + \left[e_{t-1} - (1-\lambda)\left(\hat{p}_t^{N-} - \hat{p}_t^*\right)\right]b_t^* + \left[B_t^d + (1-\lambda)b_t^*\right]\left(\pi_t - \pi_t^e\right) \tag{3.14}$$

Equation (3.10) is the domestic inflation rate[17], determined by the price variation in tradable and nontradable goods[18]. The price variation in tradable goods depends on the evolution of the exchange rate and the variation in their international prices. Producers in the nontradable sector set their prices according to a target level and responding to expected changes in the exchange rate.

Equation (3.11) is the intertemporal fiscal budget constraint. The term D_t (3.12) is the total amount of net fiscal liabilities, determined by the previous periods' decisions on expenditures and debt financing in both currencies and by the tax revenue in normal times. The term G_t^* (3.9) measures all the expenditure and debt components in foreign currency. Public debt in both currencies has the same maturity structure, which is here of one period. The term B_t^d (3.13) is the first part of the "devaluation tax" base. Hence, the revenue from surprise devaluation will be determined by the net difference[19] of two components. One is the unexpected reduction in the value of interest bearing, non-indexed, domestic currency public bonds. The other component is the extra cost incurred in purchases of tradables and interest services and payments of foreign currency public debt. Finally, to preclude the trivial solution $g_t^N = \overline{g}$ and revaluation, the "desired" fiscal expenditure will be assumed to be large enough so that the condition (3.14) will be fulfilled in every period.

The timing of the inflation stabilization plan is as follows (Fig. 3.1). **First**, the government enacts a Convertibility Law with the precommitment of the complete internal convertibility of the domestic currency as through an orthodox currency board[20]. **Second**, both the policymaker and the private sector observe period t-1 public debt stock in both currencies. **Third**, the private sector sets its devaluation expectations on the basis of the observed debt stocks and period t-1 exchange rate policy. **Fourth**, the tax revenue shock is realized during period t and is observed only by the policymaker[21]. **Fifth**, the policymaker sets its policy instruments on the basis of all observed variables and given the private sector's devaluation expectations. **Sixth**, elections take place at the end of period 2.

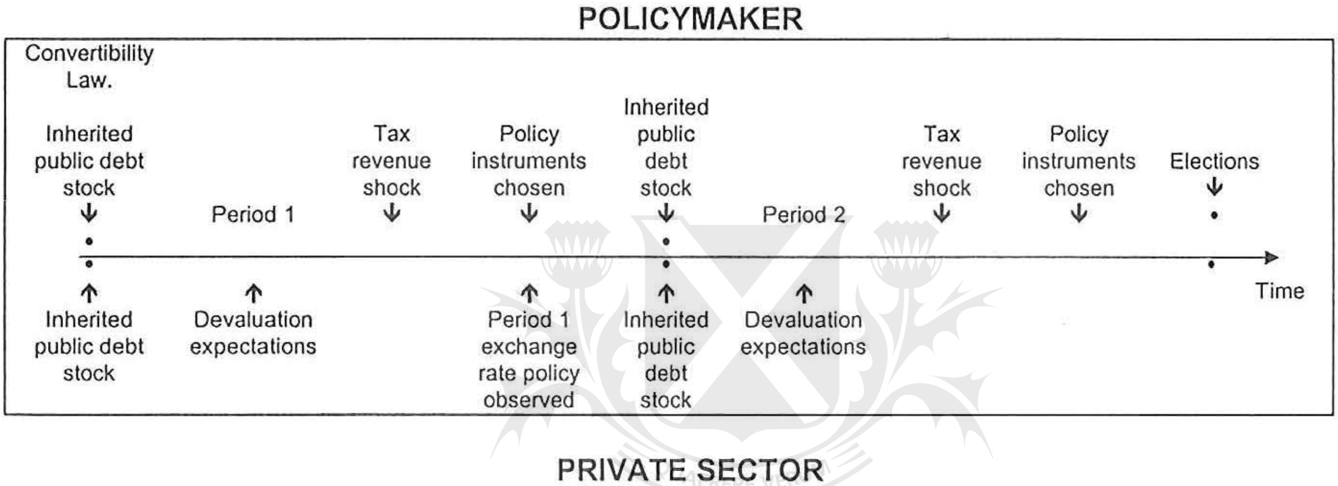


Figure 3.1- Timing of the inflation stabilization plan

3.2- Second period Nash solution

At the beginning of the second period, the policymaker inherits a debt stock in both currencies from the first period and has to decide whether to devalue or not, how much to spend on nontradables and how much to borrow in foreign currency in order to minimize (3.1) subject to (3.11), the realized tax revenue and the private sector's rational expectations of devaluation (which have been already set).

Let $L_{2,d}^c$ be the loss from devaluing and $L_{2,f}^c$ the loss from continuing with the fixed exchange rate regime, with the superscript c indicating that the loss is conditional on the realization of the tax revenue shock. Devaluation in period 2 will be optimal when the tax revenue shock is low enough that the costs of maintaining the fixed exchange rate exceed those of incurring higher inflation. Therefore, the policymaker will devalue when $L_{2,d}^c < L_{2,f}^c$ and the optimal values for the policy instruments will be:

$$\pi_2 = \frac{\alpha B_2^d (z_2 - u_2) - \lambda(1-\lambda)\left(\hat{p}_2^{N-} - \hat{p}_2^*\right) + (x_2 - \lambda)\pi_2^e}{x_2} \tag{3.15}$$

$$g_2^d = \overline{g} - \frac{\lambda\left\{\lambda(z_2 - u_2) + B_2^d\left[(1-\lambda)\left(\hat{p}_2^{N-} - \hat{p}_2^*\right) + \pi_2^e\right]\right\}}{x_2} \tag{3.16}$$

$$b_2^{*d} = 0 \tag{3.17}$$

where, $z_2 = \overline{g} + D_2 - \overline{b}_2$, $x_2 = \lambda^2 + \alpha B_2^{d2}$, and the superscript d refers to devaluation.

By using (3.15), (3.16) and (3.17) we obtain the conditional loss for the policymaker in this **discretionary devaluation equilibrium**:

$$L_{2,d}^c = \frac{\alpha\left\{\lambda(z_2 - u_2) + B_2^d\left[(1-\lambda)(\hat{p}_2^{N-} - \hat{p}_2^*) + \pi_2^e\right]\right\}^2}{2x_2} + c_2 \tag{3.18}$$

When $L_{2,d}^c > L_{2,f}^c$, the policymaker will not devalue in period 2 and so the optimal fiscal expenditure in nontradables changes to,

$$g_2^f = \overline{b}_2 - D_2 + u_2 - B_2^d \pi_2^e \tag{3.19}$$

$$b_2^{*f} = 0 \tag{3.20}$$

where the superscript f refers to fixed exchange rate.

Now, the associated conditional loss in the **non-devaluation equilibrium** becomes

$$L_{2,f}^c = \frac{\left[(1-\lambda)\left(\pi_2^e + \hat{p}_2^{N-} - \hat{p}_2^*\right)\right]^2 + \alpha\left(u_2 - z_2 - B_2^d \pi_2^e\right)^2}{2} \tag{3.21}$$

If we now compare the value of the fiscal expenditure in nontradables under both regimes, we have the following ranking:

$$0 < g_2^f < g_2^d < \overline{g} \tag{3.22}$$

This is because,

$$g_2^d - g_2^f = B_2^d \pi_2 \tag{3.23}$$

Expression (3.23) implies that the difference between the fiscal expenditure in nontradables under both regimes is higher, the higher are the base of the "devaluation tax" and the size of devaluation. We could name this difference as the "benefit of devaluation".

3.2.1- Devaluation expectations formation

We now consider the mechanism for devaluation expectations formation and evolution. They depend on the probability of devaluation, given the policymaker's preferences, which is defined as the probability that the tax revenue shock be lower than a threshold level obtained from the following "temptation" condition:

$$u_2 < z_2 + \frac{(x_2 - \lambda)\pi_2^e - \lambda(1-\lambda)(\hat{p}_2^{N-} - \hat{p}_2^*) - (2x_2c_2)^{1/2}}{\alpha B_2^d} \tag{3.24}$$

According to this condition, **the policymaker will devalue in equilibrium whenever an adverse tax revenue shock is combined with:**

1. **Large fiscal expenditure demands.**
2. **Large inherited debt stocks in both currencies.**
3. **High domestic and international interest rates.**
4. **High devaluation expectations.**
5. **A low public debt limit.**
6. **Low escape clause cost.**
7. **Also the base of the devaluation "tax" (B_2^d) plays a key role in determining the incentives to devalue.**

From the "temptation" condition (3.24), we can immediately determine the threshold level of the tax revenue shock ($\tilde{u}_2$) at which, for given z_2, π_2^e, α and c_2, the policymaker will be indifferent between devaluing or continuing with the fixed exchange rate regime:

$$\tilde{u}_2 = z_2 + \frac{(x_2 - \lambda)\pi_2^e - \lambda(1-\lambda)(\hat{p}_2^{N-} - \hat{p}_2^*) - (2x_2c_2)^{1/2}}{\alpha B_2^d} \tag{3.25}$$

It is relevant to notice in (3.25) the simultaneous dependence between $\tilde{u}_2$ and π_2^e for given z_2 and c_2: the higher the devaluation expectations, the higher the tax revenue threshold must be to keep the policymaker indifferent between devaluation and maintaining the fixed exchange rate regime; and the higher the threshold, the more likely the policymaker will be to devalue and hence devaluation expectations increase.

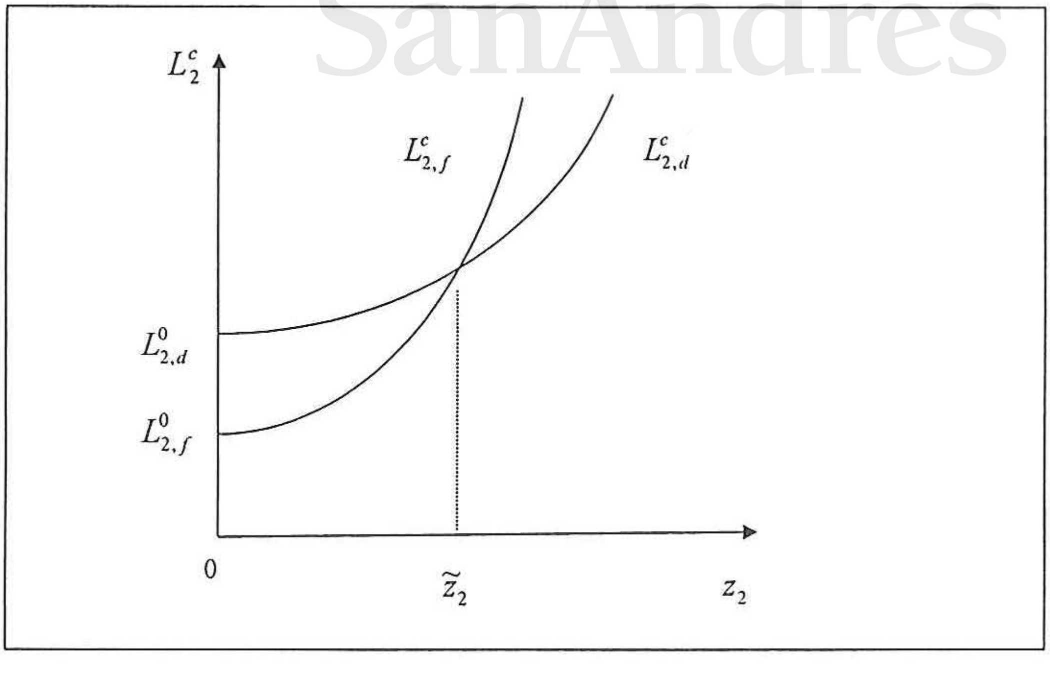


Figure 3.2- Policymaker's second period losses

Where,

$$L_{2,d}^{0}=\frac{\alpha\left\{B_2^d\left[(1-\lambda)\left(\hat{p}_2^{N-}-\hat{p}_2^{*}\right)+\pi_2^e\right]-\lambda u_2\right\}^2}{2x_2}+c_2$$

$$L_{2,f}^{0}=\frac{\left[(1-\lambda)\left(\pi_2^e+\hat{p}_2^{N-}-\hat{p}_2^{*}\right)\right]^2+\alpha\left(u_2-B_2^d\pi_2^e\right)^2}{2}$$

$$\tilde{z}_2=\tilde{u}_2-\frac{(x_2-\lambda)\pi_2^e-\lambda(1-\lambda)\left(\hat{p}_2^{N-}-\hat{p}_2^{*}\right)-(2x_2c_2)^{1/2}}{\alpha B_2^d}$$

Figure 3.3 shows the relation between $\tilde{u}_2$ and π_2^e for two alternative levels of c_2 (low and large). For each alternative, there is a critical value of π_2^e for which the threshold reaches the top value of the tax revenue shock range $(\bar{u})$. At this point, devaluation becomes a probability one event.

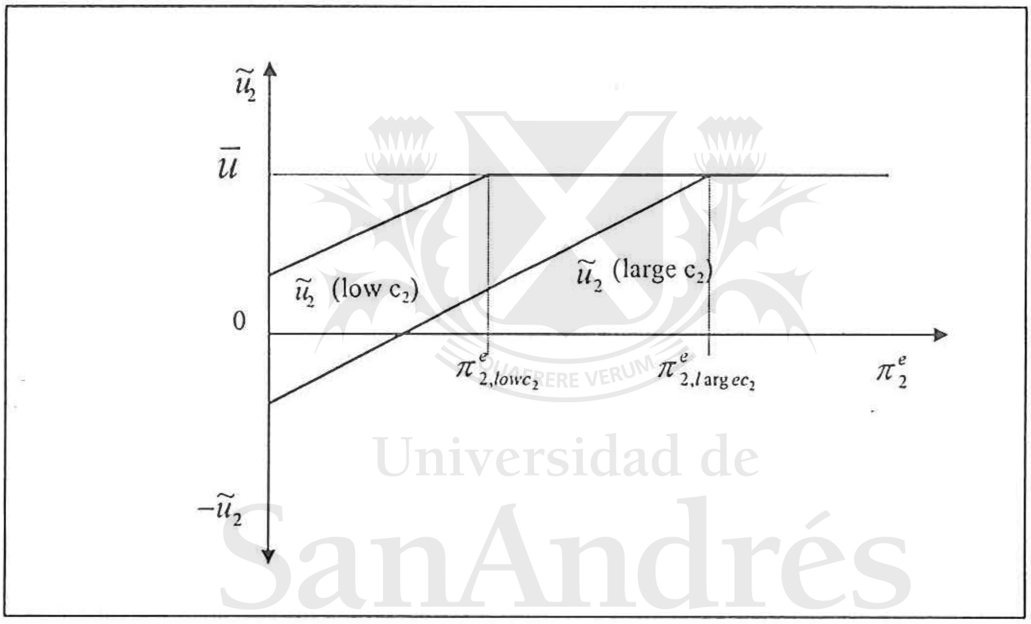


Figure 3.3- Threshold and devaluation expectations relationship

Now, the rational devaluation expectation ($E\pi_2$) for given private sector's devaluation expectations (π_2^e) is defined as the product of the probability of devaluation (q_2) and the conditional expectation $E[\pi_2/u_2<\tilde{u}_2]$. So,

$$E\pi_2=E[\pi_2/discretion]\Pr ob(discretion)=E[\pi_2/u_2<\tilde{u}_2]\Pr ob(u_2<\tilde{u}_2) \qquad (3.26)$$

where,

$$E[\pi_2/u_2<\tilde{u}_2]=\frac{\alpha B_2^{de}z_2^e-\lambda(1-\lambda)\left(E\hat{p}_2^{N-}-\hat{p}_2^{*e}\right)+(x_2-\lambda)\pi_2^e}{x_2} \qquad (3.27)$$

Given that the tax revenue shock is assumed to be uniformly distributed in the interval $[-\bar{u},\bar{u}]$, the probability of devaluation is estimated as,

$$q_2 = \text{Prob}\,[u_2 < \widetilde{u}_2] = \frac{\widetilde{u}_2^e + \overline{u}}{2\overline{u}} \tag{3.28}$$

where, $0 \le q_2 \le 1$.

By replacing (3.25) in (3.28), we determine the value of q_2 for given π_2^e,

$$q_2 = \frac{\alpha B_2^{de}\left(z_2^e + \overline{u}\right) + \left(x_2^e - \lambda\right)\pi_2^e - \lambda(1-\lambda)\left(E\hat{p}_2^{N-} - \hat{p}_2^{*e}\right) - \left(2x_2^e c_2\right)^{1/2}}{2\alpha B_2^{de}\overline{u}} \tag{3.29}$$

Then, inserting (3.27) and (3.29) in (3.26), we obtain the expression for the private sector's rational devaluation expectation,

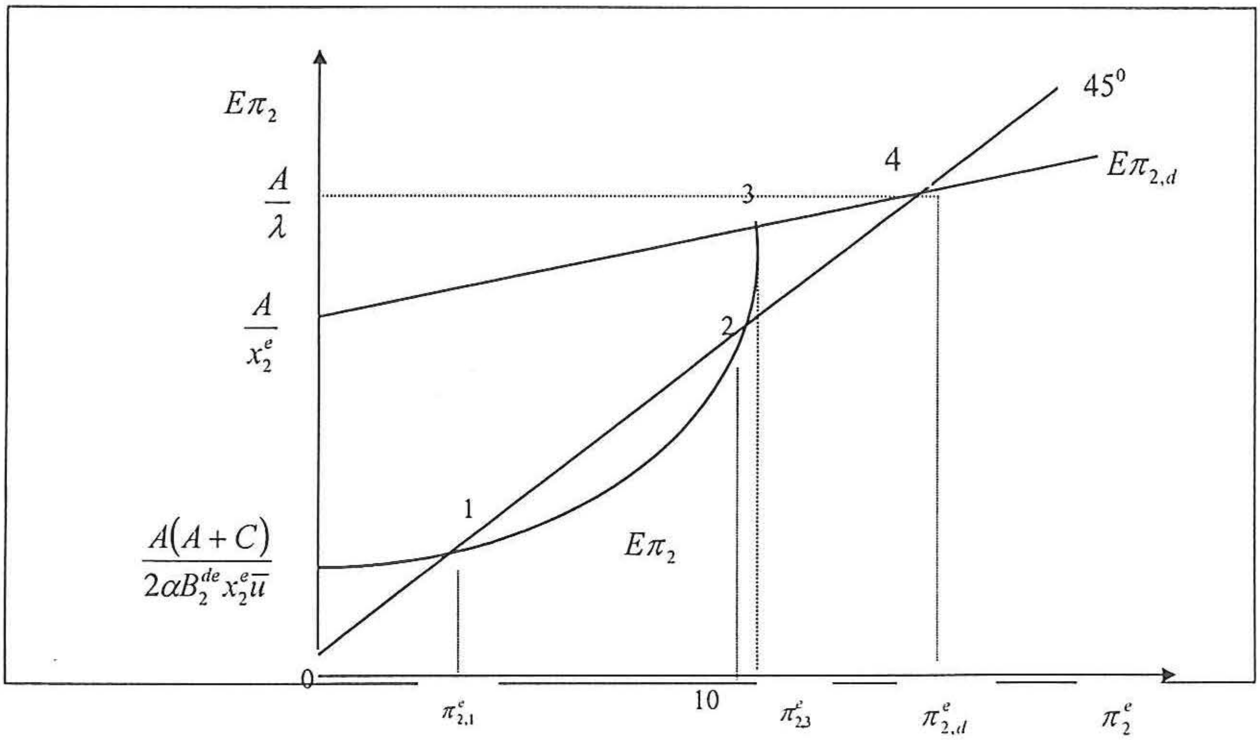
$$E\pi_2 = \frac{\left[A + \left(x_2^e - \lambda\right)\pi_2^e\right]\left[A + C + \left(x_2 - \lambda\right)\pi_2^e\right]}{2\alpha B_2^{de}\overline{u}x_2^e} \tag{3.30}$$

where, $A = \alpha B_2^{de} z_2^e - \lambda(1-\lambda)\left(E\hat{p}_2^{N-} - \hat{p}_2^{*e}\right)$, $C = \alpha B_2^{de}\overline{u} - \left(2x_2^e c_2\right)^{1/2}$.

The function $E\pi_2$ is increasing in π_2^e and convex. In full equilibrium, $E\pi_2 = \pi_2^e$, then we can derive the two solutions for π_2^e and graph them in Fig. 3.4.

$$\pi_2^e = \frac{-\left[F + 2A\left(x_2^e - \lambda\right)\right] \pm \left[F^2 - 8A\left(x_2^e - \lambda\right)\alpha B_2^{de}\overline{u}x_2^e\right]^{1/2}}{2\left(x_2^e - \lambda\right)^2} \tag{3.31}$$

where, $F = \left(x_2^e - \lambda\right)C - 2\alpha B_2^{de}\overline{u}x_2^e$.



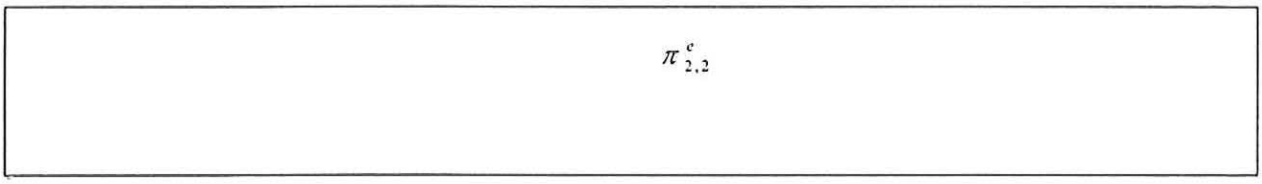


Figure 3.4- Second period devaluation equilibria[22]

Figure 3.4 shows that **there can be three equilibrium devaluation expectations (1, 2 and 4), corresponding to three different probabilities and sizes of devaluation. The pure discretionary devaluation equilibrium (4) corresponds to a probability q_2 equals to one, because $\widetilde{u}_2 = \overline{u}$. For the range of values $\left[\pi^{e}_{2,3}, \pi^{e}_{2,d}\right]$, the devaluation expectations are so high that devaluation becomes also a probability one event. Besides, the "fundamentals" $\left(z_2, \overline{u}\right)$ affect the multiplicity of equilibria by shifting the vertical intercept of $E\pi_2$ and $E\pi_{2,d}$.**

Finally, we can obtain the policymaker's expected loss for the second period under devaluation and under pegging.

$$EL_{2,d} = \frac{\alpha}{2x_2^e}\left\{\lambda z_2^e + B_2^{de}\left[(1-\lambda)\left(E\hat{p}_2^{N-} - \hat{p}_2^{*e}\right) + \pi_2^e\right]^2 + \lambda^2\sigma_u^2\right\} + c_2 \tag{3.32}$$

$$EL_{2,f} = \frac{\left[(1-\lambda)\left(\pi_2^e + E\hat{p}_2^{N-} - \hat{p}_2^{*e}\right)\right]^2 + \alpha\left[\left(z_2^e + B_2^{de}\pi_2^e\right)^2 + \sigma_u^2\right]}{2} \tag{3.33}$$

3.3- First period Stackelberg solution (work in progress)

To obtain the first period Stackelberg solution, we have to consider the effects of this period's policies on second period devaluation expectations and on the state variables. Such effects come through two variables: z_2 and B_2^d, which depend on π_1, g_1, b_1, b_1^*.

In order to derive a closed form of the optimal values for the policy instruments, we will take two simplifying assumptions. The first is that **in the first period the public debt limit in both currencies is binding.** This assumption may be justified by the low credibility that governments usually face when implementing a new stabilization plan after many previous failed attempts. This low credibility is reflected then on the lack of confidence of internal and external lenders, who constrain the amount of financing available to the government. In our model, the main consequence of this simplifying assumption will be to limit the effects' transmission channels, given that only π_1 will affect second period devaluation expectations, instead of all the policy instruments. Then, we have,

$$b_1 = \widetilde{b}_1 \tag{3.34}$$
$$b_1^* = \widetilde{b}_1^* \tag{3.35}$$

The policymaker has to minimize the following two-period loss function subject to the public debt limit, the realized tax revenue and the private sector's rational expectations of devaluation (which have been already set).

$$L_1 = \tfrac{1}{2}\left[\left(\hat{p}_1 - \hat{p}_1^*\right)^2 + \alpha\left(g_1^N - \bar{g}\right)^2\right] + c_1 + \delta\left[q_2 EL_{2,d} + \left(1 - q_2\right)EL_{2,f}\right] \tag{3.36}$$

where, $EL_{2,d}$ and $EL_{2,f}$ are given by (3.32) and (3.33).

Given the complexity of the resolution of (3.36) we will assume that q_2 takes only its two extreme values:

<u>Case A:</u> $q_2 = 1 \Rightarrow E\pi_2 = \pi_{2,d}^e = \dfrac{\alpha B_2^{de} z_2^e - \lambda(1-\lambda)\left(E\hat{p}_2^{N-} - \hat{p}_2^{*e}\right)}{\lambda}$

<u>Case B:</u> $q_2 = 0 \Rightarrow E\pi_2 = \pi_{2,f}^e = 0$

Devaluation in the first period will be optimal if $L_{1,d}^c$ < $L_{1,f}^c$ and the optimal values for the policy instruments will be:

$$\pi_1^A = \frac{\alpha\bar{B}_1^d\left(z_1 - u_1 - \bar{e}_0\tilde{b}_1^*\right) + \left(x_1 - \lambda\right)\pi_1^e - \left(1-\lambda\right)\left\{\left(\lambda - \alpha\bar{B}_1^d\tilde{b}_1\right)\left(\hat{p}_1^{N-} - \hat{p}_1^*\right) + \dfrac{\delta\alpha x_2^e\left[g^* + \left(1 + r_2^{*e}\right)\tilde{b}_1^*\right]z_2^{e'}}{\lambda^2}\right\}}{DET} \tag{3.37}$$

$$g_1^{d,A} = \bar{b}_1 - D_1 + u_1 + \left[\bar{e}_0 - \left(1-\lambda\right)\left(\hat{p}_1^{N-} - \hat{p}_1^*\right)\right]\tilde{b}_1^* + \bar{B}_1^d\left(\pi_1^A - \pi_1^e\right) \tag{3.38}$$

$$\pi_1^B = \frac{\alpha\bar{B}_1^d\left(z_1 - u_1 - \bar{e}_0\tilde{b}_1^*\right) + \left(x_1 - \lambda\right)\pi_1^e - \left(1-\lambda\right)\left\{\begin{array}{l}\left(\lambda - \alpha\bar{B}_1^d\tilde{b}_1\right)\left(\hat{p}_1^{N-} - \hat{p}_1^*\right)\\ + \delta\alpha\left[g^* + \left(1 + r_2^{*e}\right)\tilde{b}_1^*\right]\left(z_2^{e'} + B_2^{de}\pi_2^e\right)\end{array}\right\}}{DET'} \tag{3.39}$$

$$g_1^{d,B} = \bar{b}_1 - D_1 + u_1 + \left[\bar{e}_0 - \left(1-\lambda\right)\left(\hat{p}_1^{N-} - \hat{p}_1^*\right)\right]\tilde{b}_1^* + \bar{B}_1^d\left(\pi_1^B - \pi_1^e\right) \tag{3.40}$$

where,

$z_1 = \bar{g} + D_1 - \bar{b}_1$

$x_1 = \lambda^2 + \alpha\bar{B}_1^{d2}$

$\bar{B}_1^d = B_1^d + \left(1-\lambda\right)\tilde{b}_1^*$

$z_2^{e'} = \bar{g} - \bar{b}_2 + \left(1 + r_2^e\right)\tilde{b}_1^* + \left[\bar{e}_0 - \left(1-\lambda\right)\left(\pi_1^e + \hat{p}_1^{N-} - \hat{p}_1^* + E\hat{p}_2^{N-} - \hat{p}_2^{*e}\right)\right]\left[g^* + \left(1 + r_2^{*e}\right)\tilde{b}_1^*\right] - \bar{t}$

$DET = x_1 + \dfrac{\delta\alpha x_2^e\left(1-\lambda\right)^2\left[g^* + \left(1 + r_2^{*e}\right)\tilde{b}_1^*\right]^2}{\lambda^2}$

$DET' = x_1 + \delta\alpha\left(1-\lambda\right)^2\left[g^* + \left(1 + r_2^{*e}\right)\tilde{b}_1^*\right]^2$

When $L_{1,d}^c$ > $L_{1,f}^c$, the policymaker will not devalue in period 1 and so the optimal fiscal expenditure changes to,

$$g_1^{f,A} = g_1^{f,B} = \bar{b}_1 - D_1 + u_1 + \left[\bar{e}_0 - \left(1-\lambda\right)\left(\hat{p}_1^{N-} - \hat{p}_1^*\right) + \right]\tilde{b}_1^* - \bar{B}_1^d\pi_1^e \tag{3.41}$$

4- Interpretation of results and policy implications

We summarize and fully describe the second period equilibria by considering only the case when $\tilde{u}_2 /\pi_1>0 > \tilde{u}_2 /\pi_1=0$. This case[23] can be interpreted as a situation in which devaluation in the first period increases second period devaluation expectations and so the tax revenue threshold.

	$u_2 > \tilde{u}_2 /\pi_1>0$	$\tilde{u}_2 /\pi_1=0 < u_2 < \tilde{u}_2 /\pi_1>0$	$u_2 < \tilde{u}_2 /\pi_1=0$
1) $\pi_1>0$ (3.31)	Pegging $\pi_2 = 0$, (3.19), (3.20)	Devaluation (3.15), (3.16), (3.17)	Devaluation (3.15), (3.16), (3.17)
2) $\pi_1=0$ (3.31)	Pegging $\pi_2 = 0$, (3.19), (3.20)	Pegging $\pi_2 = 0$, (3.19), (3.20)	Devaluation (3.15), (3.16), (3.17)

This table show us that second period equilibria depend crucially on what has happened in the first period (devaluation or pegging) and on the realization of the tax revenue shock. In particular, when the size of the tax revenue shock is between the two thresholds ($\tilde{u}_2 /\pi_1=0 < u_2 < \tilde{u}_2 /\pi_1>0$), it is only the exchange rate policy implemented in the first period that counts for determining whether the fixed exchange rate equilibrium or a devaluation equilibrium holds in the second period.

On the other hand, when the size of the tax revenue shock is outside the range between the two thresholds, either a devaluation equilibrium (when $u_2 < \tilde{u}_2 /\pi_1=0$) or the fixed exchange rate equilibrium (when $u_2 > \tilde{u}_2 /\pi_1>0$) will hold whatever the first period exchange rate policy implemented. This result is somewhat different to that obtained by Velasco(1996a). In his model, a first period devaluation is always followed by a second period devaluation, given that it unambiguously reduces the public debt stock left behind. In our model, however, the surprise devaluation revenues are fully directed towards financing larger fiscal expenditure in nontradables rather than to reduce the public debt stock.

Regarding the losses associated with devaluation and pegging ((3.18) and (3.21)), we can observe that:

1) $L^c_{2,d}$ and $L^c_{2,f}$ are increasing in the "desired" fiscal expenditure, the inherited debt stocks in both currencies, the domestic and international interest rates, and devaluation expectations; but decreasing in the public debt limit.

2) **Discretionary devaluation would be better than continuing the fixed exchange rate rule in period 2 if $\pi_2 > \left(\frac{2c_2}{x_2}\right)^{\frac{1}{2}}$.** This is due to the "benefit" of the discretionary devaluation, that allows the policymaker to increase the fiscal expenditure in nontradables such that $g_2^f < g_2^d < \bar{g}$. In fact, as $g_2^d - g_2^f = B_2^d \pi_2$, the larger the discretionary devaluation, the higher will be the difference between the levels of fiscal expenditure in nontradables under the two regimes.

In this game structure, the policymaker has incentives to devalue in order to reduce the gap between the actual and the "desired" fiscal expenditure level. Besides the escape clause cost, a surprise devaluation increases the real exchange rate and so the costs on purchases of tradables and the following period's interest services and payments of foreign currency public debt. This cost-benefit trade-off may explain why those governments which are highly indebted and tied by commitments such as a currency board or a fixed exchange rate regime, may usually "face" a real exchange rate appreciation. In the context of these regimes, real exchange rate appreciation may be interpreted not only as a toughness signal[24], but also as a "sophisticated" device that reduces the burden of fiscal expenditure in foreign currency and so allows the government to spend more in nontradables when the fiscal pressure continue to bear.

Another important implication of the model is that a reduction of $\overline{g}$ is not only necessary but also desirable for reducing the fiscal pressure affecting the sustainability of the currency board and the credibility of the fixed exchange rate regime.

Regarding the management of the public debt's currency composition, two alternative interpretations may be drawn. The "optimistic" one would say that, given the confidence of investors on the sustainability of the convertibility program and the fixed exchange rate regime, domestic currency public bonds will be accepted by them with a reasonable financial risk premium. In this case, the government's ability to issue debt in domestic currency also constitutes a good signal to investors.

The "pessimistic" interpretation would say that when the government cannot sell its domestic currency bonds, even with a high financial risk premium, it is because investors are anticipating that the policymaker is "preparing the field" for a future devaluation, by trying to increase the base of the devaluation "tax". In contrast to the "optimistic" case, now the government's inability to issue domestic currency debt is a bad signal to investors.

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* I would like to thank Mark Salmon for helpful comments and suggestions and Daniel Heymann for inspiring discussions on the earlier drafts of this paper. The paper has also benefited from comments of seminar participants at the Macroeconomics Research Workshop (EUI). Partial financial support provided by the CONICET (Consejo Nacional de Investigaciones Científicas y

Técnicas, Argentina) through an external grant is gratefully acknowledged. I thank also the Torcuato Di Tella Institute for its hospitality. All errors and the opinions expressed are my own responsibility.

[1] See Phelps(1973), CEPAL(1986), Heymann(1986), Leijonhufvud(1990), Dornbusch et al. (1991), Easterly and Schmidt-Hebbel(1991), Canavese(1992), Heymann and Leijonhufvud(1995), Mondino et al.(1996).

[2] See Masson(1996) for the EU case.

[3] See Kyei and Yoshimura(1996) and Baliño et al. (1997) and the references indicated in them for an analysis of issues and experiences with internal convertibility and currency boards.

[4] As in Drazen and Masson(1994), Masson(1995), Masson and Agénor(1996) and Velasco(1996a,b).

[5] Recent surveys are Agénor et al. (1992), Willman(1992), Blackburn and Sola(1993), Obstfeld(1994), Jeanne(1994) and Eichegreen, Rose and Wyplosz(1994, 1995).

[6] See references indicated in the surveys cited above; and Flood et al.(1995), Lewis(1995), Obstfeld(1995), Frankel and Rose(1996).

[7] See Ozkan and Sutherland(1994a,b), Eichengreen et al. (1994, 1995), Obstfeld(1994, 1995), Bensaid and Jeanne(1995), Davies and Vines(1995), Jeanne(1995), Krugman(1996).

[8] See Tronzano(1996) for a recent survey.

[9] See Horn and Persson(1988) and Obstfeld(1991b) for early examples and Tronzano(1996), for more recent examples.

[10] See Heymann and Sanguinetti(1994), Mondino et al.(1996), among others.

[11] In our model, we consider both the "desired" fiscal expenditure and the regular taxation capacity as exogenous. However, they are the result of a political game that is not analyzed here.

[12] Finance by borrowing will be endogeneized in a repayment game to be developed in a future paper.

13 This implies that the common problems of policy coordination are ruled out. However, the consistency issues remain.

[14] Defined as units of domestic currency required to purchase one unit of foreign currency.

[15] Following Obstfeld (1991b), Cukierman, Kiguel and Liviatan(1992), Cukierman, Kiguel and Leiderman (1994), and Ozkan and Sutherland (1994a,b, 1995), among others.

[16] See Milesi-Ferretti(1995).

[17] This formulation also appears in Agénor(1994).

[18] As there is price setting in the model, aggregate product is endogenous.

[19] When this net difference is positive(negative), devaluation (pegging) may be the optimal policy.

[20] An interesting question to be raised is when it would be desirable to establish an orthodox currency board.

[21] This information advantage can be reasonably justified by the fact that data on tax revenues are always available first to the policymaker.

[22] A relatively similar figure appears in Obstfeld(1995).

[23] The other case with the opposite inequality is also possible for certain set of parameters.

[24] See Winckler(1991).