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Balance of Payments Crises Under Inflation Targeting

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Research

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Abstract

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This paper analyzes a small open economy model under inflation targeting. It shows why such a monetary regime is vulnerable to speculative attacks that take place over a short period rather than instantaneously. The speed at which the regime collapses, and the extent of reserve losses, are increasing in the central bank's explicit or implicit commitment to intervene in the foreign exchange market. Attacks are therefore ranked, from most to least severe, as follows: Exchange rate targeting, CPI inflation targeting, domestic nontradables inflation targeting, and money targeting. Under inflation targeting the size of the attack is increasing in the tradables consumption share.

JEL Classification Numbers:

Keywords: Balance of payments crisis, inflation targeting, exchange rate targeting, foreign exchange intervention, flow speculative attack

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I. Introduction

This paper analyzes a small open economy model under monetary regimes that target inflation. It distinguishes between consumer price index (CPI) inflation targets and domestic nontradables inflation targets. It is explained why such regimes are vulnerable to speculative currency attacks that take place over a short period of time rather than instantaneously as under exchange rate targeting. The severity of attacks, measured by the speed at which the regime collapses, or alternatively by the extent of reserve losses, is increasing in the central bank's explicit or implicit commitment to intervene in the foreign exchange market. This commitment is strongest under exchange rate targeting, and successively weaker for CPI inflation targeting, domestic inflation targeting, and money targeting. These theoretical points are general, but they appear to us to be most relevant to emerging markets.

Inflation targeting started to be used by the central banks of several advanced economies in the early 1990s. The list of countries now using it includes Australia, Canada, Finland, New Zealand, Sweden, and the UK. It is widely perceived as having been successful there, see the discussions in Leiderman and Svensson (1995), McCallum (1996) and Bernanke, Laubach, Mishkin and Posen (1999). Inflation targeting is now increasingly being used or considered by emerging economies. Following the currency turmoil of the Mexican, Asian, Russian and Brazilian crises, several of them have had to let their currencies float. The task has shifted from crisis management to designing a new permanent monetary policy framework. There is a widely shared view that for emerging economies the option of simply fixing the exchange rate is no longer viable, and that the choice is between a fixed exchange rate with a very strong form of commitment (such as a currency board or full dollarization) and flexible exchange rates.[1] Several emerging economies such as Brazil, Chile, Colombia, Mexico and Poland have chosen the latter. Given the well-known problems associated with choosing a monetary aggregate as the nominal anchor, they have opted for an inflation target.

In the policy debate one of the major advantages of inflation targeting is often claimed to be that it does not leave an economy vulnerable to a speculative attack. The logic is that a run on reserves can be averted because the central bank can simply let the exchange rate go. In this paper we show that, if the policymaker is fully committed to the inflation target, this is generally not correct. The reason is that in an open economy an inflation target always implies a commitment to intervene in the foreign exchange market to defend that target. That commitment makes a speculative attack possible.

We choose as our expository device a simple but fully microfounded first generation balance of payments crisis model related to Calvo (1987). The model includes both tradable and nontradable goods, which allows a natural specification of the CPI. Extensions to second generation speculative attacks are possible. As discussed in Krugman (1996), these also require a commitment to intervene in the foreign exchange market to defend a target plus some form of vulnerability.[2] Furthermore, in our opinion

[1] Several influential researchers disagree with this new orthodoxy, see e.g. Frankel (1999) and the discussion in Mishkin and Savastano (2000).

[2] In fact, as described by Carstens and Werner (1999) and Morande and Schmidt-Hebbel (1999), contagion-driven speculative attacks on inflation targets did happen in Mexico, Chile and Israel (among others) in 1998, following the Asian and Russian crises. The Chilean case is discussed in more detail in Section 4.2, along

first generation models are still a very appropriate framework for many emerging markets. As discussed in Masson, Savastano and Sharma (1997), in most of these economies the government budget remains a source of instability. The reasons include a weak fiscal revenue base, a rudimentary tax collection system, the contingent bailout liabilities attached to weak banking systems, and simple overspending at the federal or regional level. There is therefore a real danger, much more so than among industrial country inflation targeters, that only the monetary part of an inflation targeting program may be adequately implemented, just as has so often been the case in the past for exchange rate based stabilizations.

Our paper is part of the large literature on inflation stabilization and balance of payments crises in developing countries that is surveyed in Calvo and Vegh (1999). Their survey concentrates on the qualitative dynamics of two types of monetary stabilization regimes, exchange rate and money targeting. The susceptibility of the former to balance of payments crises is analyzed, while money targeting is by definition immune to a speculative attack. Our work can be seen as filling in the gap between these two extremes of monetary policy by analyzing two examples from the most popular range of intermediate regimes, inflation targeting. Unlike Calvo and Vegh (1999), our paper examines the detailed quantitative implications of a failed inflation stabilization in a dynamic general equilibrium setup. The key papers in the literature that do this for exchange rate based stabilizations are Mendoza and Uribe (2000, 2001).

We show that towards the end of an unsustainable domestic inflation targeting regime there is upward pressure on exchange rate depreciation and an associated contraction in goods and money demand caused by the increasing inflationary distortions. To stabilize inflation in the face of a drop in money demand, the central bank needs to intervene by buying money against foreign exchange. Under CPI inflation targeting reserve losses are even larger, because in this case there is a stronger commitment to intervene. The reason is that, while permitting exchange rate depreciation under domestic inflation targeting does not directly affect the targeted inflation rate, the same depreciation does lead to a deviation from a CPI inflation target. A further contraction of the money supply is therefore required to induce nontradables deflation and to reduce exchange rate depreciation. This commitment to intervene is increasing in the share of tradable goods in overall demand, because a larger share increases the inflationary consequences of exchange rate depreciation and therefore forces a larger offsetting monetary contraction. Exchange rate targeting is the limiting case, where the monetary policy commitment to foreign exchange intervention is explicit and stronger than for all other regimes. Therefore the reserve losses, which happen instantaneously, are largest. These conclusions regarding the relative vulnerability to speculative attacks give some support to domestic inflation targeting, a monetary regime that has been found to perform well in a different context, namely in dynamic general equilibrium open economy models with nominal rigidities and subjected to foreign shocks.[3,4]

The rest of the paper is organized as follows. Section 2 develops the model. Section 3 discusses model calibration and the solution algorithm. Section 4 contains a discussion of

with the Brazilian attacks of 2001/2, which did reflect perceived problems with economic fundamentals.

[3] See Gali and Monacelli (2002) for a statement of this case.

[4] In this paper we assume flexible prices, which greatly simplifies the analytical and computational aspects of the model while allowing us to focus squarely on the logic of speculative attacks.

the dynamics of balance of payments crises under the different monetary regimes. Section 5 concludes. Technical details and a description of the solution algorithm are contained in the Technical Appendix accompanying this paper.

II. The Model

Consider a small open economy that consists of a government, representative households, and representative tradables and nontradables manufacturing firms. Lower/upper case letters represent real/nominal quantities, and an asterisk represents variables in the tradables sector. For tradable goods purchasing power parity holds[5] and their international price is constant and normalized to one. Nontradable goods prices are flexible.

A. Households

Households maximize lifetime utility derived from consumption of tradable goods c_t^*, nontradable goods c_t, and leisure $1 - L_t$, where 1 is the time endowment and L_t is labor supply. The consumption aggregator C_t has constant elasticity of substitution σ between c_t^* and c_t. The personal discount rate equals the constant real international interest rate r. The objective function is

$$Max \quad \int_0^\infty \left[\gamma \ln C_t + (1-\gamma)\ln(1-L_t)\right] e^{-rt} dt \ , \tag{1}$$

$$C_t = D_t^{\frac{\sigma}{\sigma-1}} = \left(\omega^{\frac{1}{\sigma}} (c_t^*)^{\frac{\sigma-1}{\sigma}} + (1-\omega)^{\frac{1}{\sigma}} (c_t)^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}} \ . \tag{2}$$

We denote the nominal exchange rate, the price level of nontradables and the nominal wage by E_t, P_{N_t} and W_t respectively. The relative price of tradables is given by $e_t = E_t/P_{N_t}$, the real wage in terms of tradables by $w_t = W_t/E_t$, and the rate of currency depreciation by $\varepsilon_t = \dot{E}_t/E_t$. Households receive income from their supply of labor and capital to firms, from tradables and nontradables producing firms' lump-sum profit redistributions $\Pi_t^* + \Pi_t/e_t$ and from government lump-sum transfers g_t. Labor L_t is remunerated at w_t, which is equalized across sectors. Households own fixed stocks of capital k^* and k used in the tradables and nontradables manufacturing sectors, with returns in terms of tradable goods denoted by $r_t^{k^*}$ and r_t^k. Households hold three types of financial assets, nominal money balances M_t, real international bonds $\tilde{b}_t$ denominated in foreign currency and earning a constant real rate of return r, and domestic currency denominated government bonds Q_t earning a nominal rate of return i_t. We assume that domestic currency bonds can only be held by domestic residents. Letting $q_t = Q_t/E_t$ and $m_t = M_t/E_t$, total real financial asset holdings equal $a_t = \tilde{b}_t + q_t + m_t$. The no-arbitrage condition between domestic and foreign currency denominated bonds, or uncovered interest parity, is given by:

$$i_t = r + \varepsilon_t \ . \tag{3}$$

[5] The theoretical literature emphasizes that permanent exchange rate changes, such as the ones exhibited in a speculative attack model, are associated with high pass-through. See Froot and Klemperer (1989), Krugman (1989) and Dixit (1989).

Foreign and domestic currency denominated bonds are therefore perfect substitutes, and their shares in households' portfolios are indeterminate. We make the additional assumption that $Q_0 = 0$, which implies that we can, without loss of generality, conduct our analysis in terms of the sum, $b_t = \tilde{b}_t + q_t$. Households face the following flow budget constraint in terms of tradables:

$$\dot{b}_t = rb_t + w_t L_t + r_t^{k^*} k^* + r_t^k k + \Pi_t^* + \frac{\Pi_t}{e_t} + g_t - c_t^* - \frac{c_t}{e_t} - \dot{m}_t - \varepsilon_t m_t \ . \tag{4}$$

After imposing the transversality condition $\lim_{t \to \infty} a_t e^{-rt} \geq 0$, the lifetime budget constraint can be written as

$$a_0 + \int_0^\infty \left(w_t L_t + r_t^{k^*} k^* + r_t^k k + \Pi_t^* + \frac{\Pi_t}{e_t} + g_t \right) e^{-rt} dt \geq \int_0^\infty \left(c_t^* + \frac{c_t}{e_t} + i_t m_t \right) e^{-rt} dt \ . \tag{5}$$

There is a cash-in-advance constraint on consumption

$$m_t \geq \alpha \left(c_t^* + \frac{c_t}{e_t} \right) \ , \tag{6}$$

which holds with equality as long as the nominal interest rate is strictly positive. This will be assumed in the following analysis, and will be shown to hold in equilibrium. The household's problem is to maximize (1) and (2) subject to (5) and (6), with (6) binding, taking as given $\left\{ w_t, r_t^{k^*}, r_t^k, \Pi_t^*, \Pi_t, g_t, E_t, P_{N_t} \right\}_{t=0}^{\infty}$. We denote the multiplier of the lifetime budget constraint (5) by λ. Then the optimality conditions are (5) and (6) holding with equality, and the following first-order conditions for c_t^*, c_t and L_t:

$$c_t^* = \left(\frac{\gamma \omega^{\frac{1}{\sigma}}}{\lambda \left(1 + \alpha i_t \right) D_t} \right)^{\sigma} \ , \tag{7}$$

$$c_t = \left(\frac{\gamma (1-\omega)^{\frac{1}{\sigma}} e_t}{\lambda \left(1 + \alpha i_t \right) D_t} \right)^{\sigma} \ , \tag{8}$$

$$\lambda w_t = \frac{1-\gamma}{1-L_t} \ . \tag{9}$$

Equations (7) and (8) can be combined to yield

$$c_t^* = \left(\frac{\omega}{1-\omega} \right) \left(\frac{c_t}{e_t^{\sigma}} \right) \ . \tag{10}$$

The implied values for real balances in terms of tradables and nontradables are

$$m_t = \frac{M_t}{E_t} = \alpha c_t^* \left(1 + e_t^{\sigma-1} \frac{1-\omega}{\omega} \right) \ , \tag{11}$$

$$n_t = \frac{M_t}{P_{N_t}} = \alpha c_t \left(1 + e_t^{1-\sigma} \frac{\omega}{1-\omega} \right) \ . \tag{12}$$

The model counterpart of the CPI, which we will denote by P_t, is the consumption based price index. Given the presence of both tradable and nontradable goods in the consumption basket C_t, the exchange rate is an important component of P_t:

$$P_t = \left(\omega E_t^{1-\sigma} + (1-\omega) P_{N_t}^{1-\sigma} \right)^{\frac{1}{1-\sigma}} \ . \tag{13}$$

Letting $p_t = \dot{P}_t/P_t$ and $\pi_t = \dot{P}_{N_t}/P_{N_t}$ we also have the following relationship between inflation rates:

$$p_t\left(\omega e_t^{1-\sigma} + (1-\omega)\right) = \omega e_t^{1-\sigma}\varepsilon_t + (1-\omega)\pi_t \ . \tag{14}$$

The cost minimization underlying (13) implies that $E_t c_t^* + P_{N_t} c_t = P_t C_t$. After rewriting the budget constraint accordingly we can therefore obtain an optimality condition for aggregate consumption. By combining this with the optimality condition for aggregate labor (9) we obtain

$$w_t^{cpi} = \frac{W_t}{P_t} = \frac{1-\gamma}{\gamma}\frac{C_t(1+\alpha i_t)}{1-L_t} \ . \tag{15}$$

Equation (15) shows that deviations of the nominal interest rate from the Friedman rule create a monetary distortion in consumption and labor supply that is equivalent to a labor income (or consumption) tax. Because in our model different monetary regimes have different implications for the time path of i, our results for the dynamics of real variables during crises can therefore be attributed to the effects of monetary policy on the time profile of these tax-like distortions. It can also be shown (see the Technical Appendix) that the rate of change of tradables consumption is a function of the rate of change of nominal interest rates. Time variations in nominal interest rates therefore act like a tax on saving that alters the intertemporal relative price of tradables consumption, with increasing nominal interest rates giving rise to a decreasing consumption profile.[6]

B. Firms

The production functions of tradables and nontradables manufacturing firms are given by

$$y_t^* = (k^*)^{\rho^*}(\ell_t^*)^{1-\rho^*} \ , \tag{16}$$

$$y_t = k^\rho \ell_t^{1-\rho} \ , \tag{17}$$

where ℓ_t^* and ℓ_t are the respective labor inputs. Profit maximization implies the following first order conditions for labor in each sector:

$$(1-\rho^*)\left(\frac{k^*}{\ell_t^*}\right)^{\rho^*} = w_t \ , \tag{18}$$

$$(1-\rho)\left(\frac{k}{\ell_t}\right)^{\rho} = e_t w_t \ , \tag{19}$$

where $e_t w_t$ is the real wage in terms of nontradable goods. The constant returns to scale technology ensures that firm profits equal $\Pi_t^* = \Pi_t = 0$.

C. Government

The government's policy consists of a specification of the path of lump-sum transfers $\{g_t\}_{t=0}^{\infty}$, and of a monetary policy rule. We consider three different rules, namely exchange rate targeting, CPI inflation targeting and domestic inflation targeting. We also briefly discuss money targeting. The initial target inflation rates under the respective regimes are denoted by $\bar{\varepsilon}$, $\bar{p}$, and $\bar{\pi}$. These target growth rates are assumed to have been sustainable

[6] See Mendoza and Uribe (2000, 2001) for very similar arguments.

under a previous path of transfers, but they become unsustainably low given a new path of transfers $\{g_t\}_{t=0}^{\infty}$ announced at time 0. The eventual steady state target growth rates will be determined by a balanced budget requirement for the government.

For exchange rate targeting we simply have a target path for the nominal anchor:

$$E_t = E_{0+}e^{\bar{\varepsilon}t} \; . \tag{20}$$

The initial condition for the path of the nominal anchor is a function of the degree of central bank accommodation, upon the announcement of a new policy at time 0, of changes in real money demand m_t through changes in the nominal money supply M_t. Two cases will be considered for each monetary regime. One is full accommodation and therefore a smooth path of the nominal exchange rate. The other is monetary accommodation that instead ensures smooth paths of the targeted price variable, i.e. of P_t or P_{N_t} under one of the two inflation targeting regimes. Full accommodation increases reserves by identical amounts on impact under all regimes[7] while keeping the exchange rate constant. As a result there are discontinuous jumps in P_{N_t} and P_t. This assumption is not only quite plausible[8], it also has the advantage of eliminating differences in initial reserves as a source of differences in crisis timing. By contrast, smooth target price levels are associated with discrete nominal exchange rate jumps on impact, so that a given increase in real money demand does not lead to a one for one increase in foreign exchange reserves.

Under inflation targeting the policy instrument of the central bank is different from the target variable. The literature typically assumes that the central bank follows a rule for the nominal interest rate on domestic currency bonds that responds to deviations of inflation from its target. However, under flexible prices as in our model such a rule can give rise to indeterminacy. One way to deal with this problem, which we adopt here, is to assume that the nominal interest rate is increasing in deviations of the price path from its targeted path. The target price paths $\tilde{P}_t$ and $\tilde{P}_{N_t}$ are formulated as in the exchange rate rule (20), i.e. they allow for initial price level jumps that are driven by monetary accommodation alone. Furthermore, the nominal interest rate is raised one for one with the current rate of exchange rate depreciation - a further discussion of this assumption is provided in the next subsection. For CPI inflation targeting we therefore have the rule

$$i_t^P = r + \varepsilon_t + \xi^P(P_t - \tilde{P}_t) \; , \; \xi^P > 0 \; , \tag{21}$$

$$\tilde{P}_t = P_{0+}e^{\bar{p}t} \; , \tag{22}$$

and similarly for domestic inflation targeting

$$i_t^{P_N} = r + \varepsilon_t + \xi^{P_N}(P_{N_t} - \tilde{P}_{N_t}) \; , \; \xi^{P_N} > 0 \; , \tag{23}$$

$$\tilde{P}_{N_t} = P_{N_{0+}}e^{\bar{\pi}t} \; . \tag{24}$$

For the sake of completeness, a money target is, like an exchange rate target, directly under the central bank's control, and takes the form $M_t = M_{0+}e^{\bar{\mu}t}$, where $\mu_t = \dot{M}_t/M_t$.

[7] There are some extremely small differences in the initial jumps in real money demand between regimes. We have verified that these are so small as to not affect our quantitative analysis at any reasonable precision.

[8] Calvo and Reinhart (2002) and Reinhart (2000) show that central banks in emerging economies continue to resist large swings in nominal exchange rates.

Let h_t be the government's foreign exchange reserves, defined as its holdings of foreign currency bonds net of its (perfectly substitutable) domestic currency bond liabilities. Then the government's flow budget constraint is

$$\dot{h}_t = rh_t + \dot{m}_t + \varepsilon_t m_t - g_t = rh_t + \mu_t m_t - g_t \ , \tag{25}$$

where $\mu_t m_t$ is the amount of seigniorage the central bank collects. At times of discrete jumps in nominal money balances between t^- and t the following must hold for foreign exchange reserves:

$$h_t - h_{t-} = \Delta m_t^M = (M_t - M_{t-})/E_t = dM_t/E_t \ . \tag{26}$$

Note that real money balances can also change discretely because of jumps in the nominal exchange rate, $\Delta m_t^E = M_{t-}\left(\frac{1}{E_t} - \frac{1}{E_{t-}}\right)$. Such jumps are not associated with a change in foreign exchange reserves. There is a minimum level of net foreign assets, which for simplicity will be assumed to be equal to zero:[9]

$$h_t \geq 0 \quad \forall t \ . \tag{27}$$

In addition we impose the transversality condition $\lim_{t\to\infty} (h_t - m_t)\, e^{-rt} = 0$ to obtain the government's infinite horizon budget constraint from (25) as follows:

$$h_0 + \int_0^\infty i_t m_t e^{-rt} dt = m_0 + \int_0^\infty g_t e^{-rt} dt \ . \tag{28}$$

D. Equilibrium

A *government policy* is defined as a list of time paths for interest rates and government spending such that (26), (27) and (28) hold for all t. An *allocation* is a list of time paths $\{b_t, h_t, m_t, c_t^*, c_t, y_t^*, y_t, \ell_t^*, \ell_t, L_t\}_{t=0}^\infty$, and a *price system* is a list of time paths $\{E_t, P_{N_t}, P_t, W_t, r_t^{k^*}, r_t^k\}_{t=0}^\infty$. Finally let $f_t = b_t + h_t$, the economy's overall net foreign assets. Then a *perfect foresight equilibrium* given f_0 is an allocation, a price system, and a government policy such that, given the government policy and the price system, the allocation solves the optimization problems of households and manufacturing firms, and the labor and goods markets clear:

$$L_t = \ell_t^* + \ell_t \ , \tag{29}$$

$$c_t = y_t \ . \tag{30}$$

Combining (5) and (28) the economy's overall resource constraint can then be derived as

$$f_0 + \int_0^\infty y_t^* e^{-rt} dt = \int_0^\infty c_t^* e^{-rt} dt \ , \tag{31}$$

with current account

$$\dot{f}_t = rf_t + y_t^* - c_t^* \ . \tag{32}$$

[9] See Obstfeld (1986) for a discussion of this constraint. It is highly relevant for emerging economies, which as documented by Calvo and Reinhart (2002) lose access to international capital markets during balance of payments crises.

Furthermore, for the two inflation targeting regimes, in equilibrium it must be true that $i_t^P = i_t$ and $i_t^{P_N} = i_t$. Together with the uncovered interest parity condition (3) this implies

$$P_t = P_{0+}e^{\bar{p}t} \ , \tag{33}$$

$$P_{N_t} = P_{N_{0+}}e^{\bar{\pi}t} \ . \tag{34}$$

These are analogous to equation (20) for exchange rate targeting, and amount to exact price level targeting. To gain further intuition for this result, we now show that it represents the limiting case of a feedback rule that allows for temporary deviations of the price path from its target path. Consider the rule

$$i_t^P = r + \kappa\varepsilon_t + \xi^P(P_t - \tilde{P}_t) \ , \ \xi^P > 0 \ , \ \kappa < 1 \tag{35}$$

for CPI inflation targeting. Uncovered interest parity (3) eliminates arbitrage opportunities between domestic and foreign currency bonds by driving the rate of exchange rate depreciation to $\varepsilon_t = \left(\xi^P/(1-\kappa)\right)(P_t - \tilde{P}_t)$. As a result, the effective interest rate rule is[10]

$$i_t^P = r + \frac{\xi^P}{1-\kappa}(P_t - \tilde{P}_t) \ . \tag{36}$$

Our rule (21) is the limiting case of (35) as $\kappa \longrightarrow 1$. By (36) this corresponds to a feedback rule (with an inflation target of zero) that places an infinite weight on deviations of the price path from its target path. Together with flexible prices this implies that no deviations occur at any time, and we obtain (33) (and (34) for domestic inflation targeting).

E. Unsustainable Policy

Assume that the economy is in an initial (subscript I) steady state with constant net foreign assets f_I and foreign exchange reserves h_I, and with a balanced budget. In this steady state all rates of price change are equal to the initial target growth rate of the nominal anchor. We assume that $f_I = 0$ and that $p_I = \varepsilon_I = \pi_I = 0$. Therefore the budget is simply

$$g_I = rh_I \ . \tag{37}$$

Now assume that the government starts to pursue an inconsistent monetary-fiscal policy mix at $t = 0$, with the target growth rate of the nominal anchor kept at 0 under all three monetary regimes while government transfers are permanently increased from g_I to $\bar{g}$, where $\bar{g} > rh_I$. By (25) this generates a gradual and ultimately complete depletion of foreign exchange reserves, so that within finite time T the constraint (27) becomes binding, the regime collapses, and the economy reaches its final (subscript T) steady state. The time T is endogenous. Given that the constraint (27) is binding for all $t \geq T$, the budget must be balanced through higher seigniorage income from that time onwards:

$$\bar{g} = \varepsilon_T m_T \ , \tag{38}$$

where $\varepsilon_T > 0$. It is shown in the Technical Appendix that under CPI and domestic inflation targeting ε_t must be continuous for all $t > 0$ including T.

[10] As under any interest rate policy, the central bank allows the money supply to move endogenously to hit its target.

III. Model Solution

A. Parameter Values

Where available, parameters are assigned based on Brazilian data for the initial four years of that country's inflation targeting regime, 2000-2003. Brazil is one of the first developing countries to have experienced speculative attacks after the adoption of inflation targeting. Other parameter values are assigned based on the literature for developing countries. The time unit for calibration of stock-flow ratios is a quarter.

For a developing country the real marginal cost of borrowing in international capital markets r is assumed to be given by the real Brady bond yield. In Brazil this fluctuated between 10% and 15%, which after adjusting for US inflation suggests using an annual real interest rate of 10%. The inverse velocity α is set equal to the ratio of real monetary base to quarterly absorption in Brazil, implying $\alpha = 0.33$. The share parameter for tradables consumption ω is set equal to $\omega = 0.5$. The elasticity of substitution between tradables and nontradables is set to $\sigma = 0.5$, based on the evidence discussed in Mendoza (2005). Several of the remaining parameters are calibrated based on a normalization of output and asset stocks in the initial steady state. We normalize $f_I = 0$, $y_I^* = c_I^* = 1$ and $y_I = c_I = 1$. By (10), and given our choice of $\omega = 0.5$, this implies an initial relative price of tradables e of one. This in turn implies that the initial share of tradables in consumption is equal to 0.5 in our baseline case, which is empirically reasonable based on the work of De Gregorio, Giovannini and Wolf (1994). The proportion of time spent working in the initial steady state is assumed to be $\bar{L} = 1/3$. For many developing countries, NIPA data show factor income shares that are nearly opposite to those in the US. But García-Verdú (2005), by correcting the treatment of the income of the self-employed in Mexico, finds that labor shares are about the same as in the US. We assume that the same is true for Brazil, and as we have no information about sectorial differences we assume $\rho^* = \rho = 0.4$. The preceding assumptions can be shown to imply $\gamma = 0.62$. As for the price variables, the initial CPI price level P is normalized to one. Then the formula for the CPI determines the price levels P_N and E, and (11) and (12) determine the levels of real and nominal balances. Central bank foreign exchange reserves h_I are set at $0.987 * m_I$, based on the h/m-ratio in Brazil in 2000, at the beginning of the inflation targeting regime and prior to speculative attacks in 2001/2. Initial government spending is set to be equal to the interest earnings on these reserves so as to balance the budget. It equals $g_I = 0.016$. The new and permanently higher government transfer is assumed to be $\bar{g} = 0.2$. A large value was chosen mainly for computational reasons and implies a fast speculative attack. Qualitatively this does not affect the comparative dynamics of speculative attacks under the three regimes considered here.

B. Solution Method

To compute the paths of all variables we adopt a nested shooting algorithm for the CPI and domestic inflation targeting cases, because these cases involve complicated transitions to a new steady state. The general strategy is to iterate over the marginal value of lifetime wealth λ and the initial exchange rate jump ε_0 to ensure that - given the unsustainable policy announced at time 0 - equilibrium paths satisfy both the economy's overall resource constraint (31), and the government's lifetime budget constraint (28) combined with the lower bound on foreign exchange reserves (27). The steps of the algorithm are described in detail in the Technical Appendix.[11]

IV. The Dynamics of Speculative Attacks

A. Model Dynamics

Figure 1 presents solution paths for the full accommodation case. For domestic inflation targeting (DIT) it displays dotted lines, for CPI inflation targeting (CPIT) solid lines, and for exchange rate targeting (ET) broken lines. The dynamics of speculative attacks under the three monetary regimes share a number of features. At time 0 households learn that the government has embarked on an ultimately unsustainable policy of higher spending. This must eventually lead to higher inflation, but during an initial period the government manages to maintain a tight monetary policy by drawing on its foreign exchange reserves. The fact that inflationary distortions will be higher in the future leads households to engage in intertemporal substitution - by (7) and (8) there will be an initial consumption boom followed by a collapse of consumption when the higher inflation materializes. By the cash-in-advance constraint real money balances will therefore initially rise and then collapse. As is well known, under exchange rate targeting this final collapse in reserves is instantaneous. The reduction in real money balances is accomplished through an exchange for the remaining stock of central bank foreign exchange reserves. In the remaining two cases the increase in inflation and the nominal interest rate is not abrupt, but it is nevertheless concentrated in a short period before the final collapse of the regime. There is therefore a continuous but sharply accelerating drop in consumption demand and therefore in money. The extent of the associated reserve losses, as we will show, depends on the monetary regime.

The tradables consumption demand boom at the outset of the stabilization program leads to a larger current account deficit. Tradables are supplied perfectly elastically by world markets. Nontradables consumption on the other hand is constrained by less elastic domestic production. The consequence of these differences in supply elasticities is a large increase in the relative price of nontradables, or a decrease in e. This implies that nontradables consumption increases by much less than tradables consumption, but at the same time higher nontradables prices give a boost to nontradables production, and they provide an incentive for that sector to hire more labor at a higher nominal wage. Because monetary policy initially keeps the exchange rate from depreciating, this nominal wage increase translates to a large increase in the real wage w faced by tradables producers, which leads to an output collapse in that sector and a further widening of the current account gap.

[11] Computation of the exchange rate targeting case is much simpler, as it involves simple step paths for all variables. Details are also provided in the Technical Appendix.

Figure 1: (a) Overview (Full Accommodation)

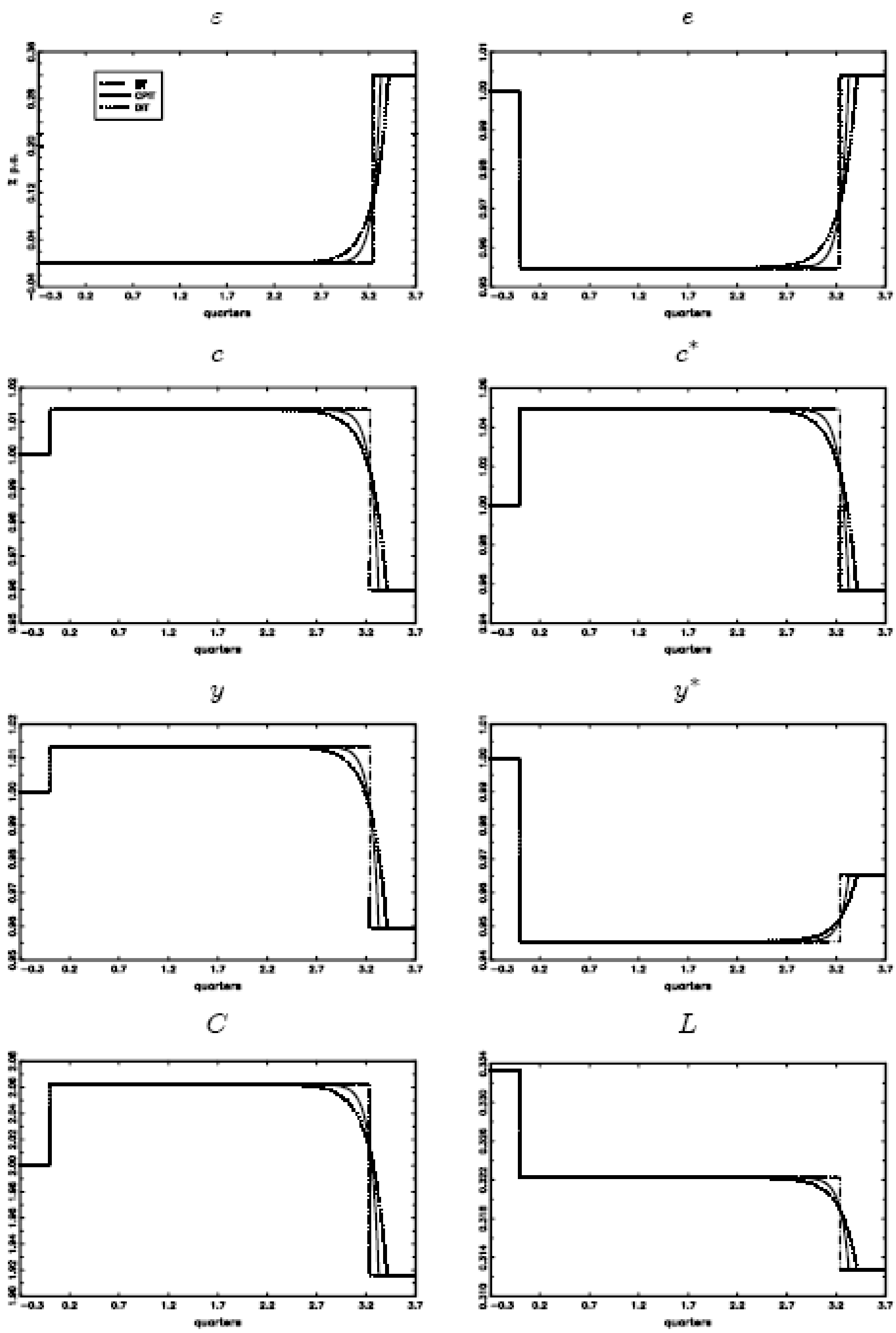


Figure 1: (b) Labor Market (Full Accommodation)

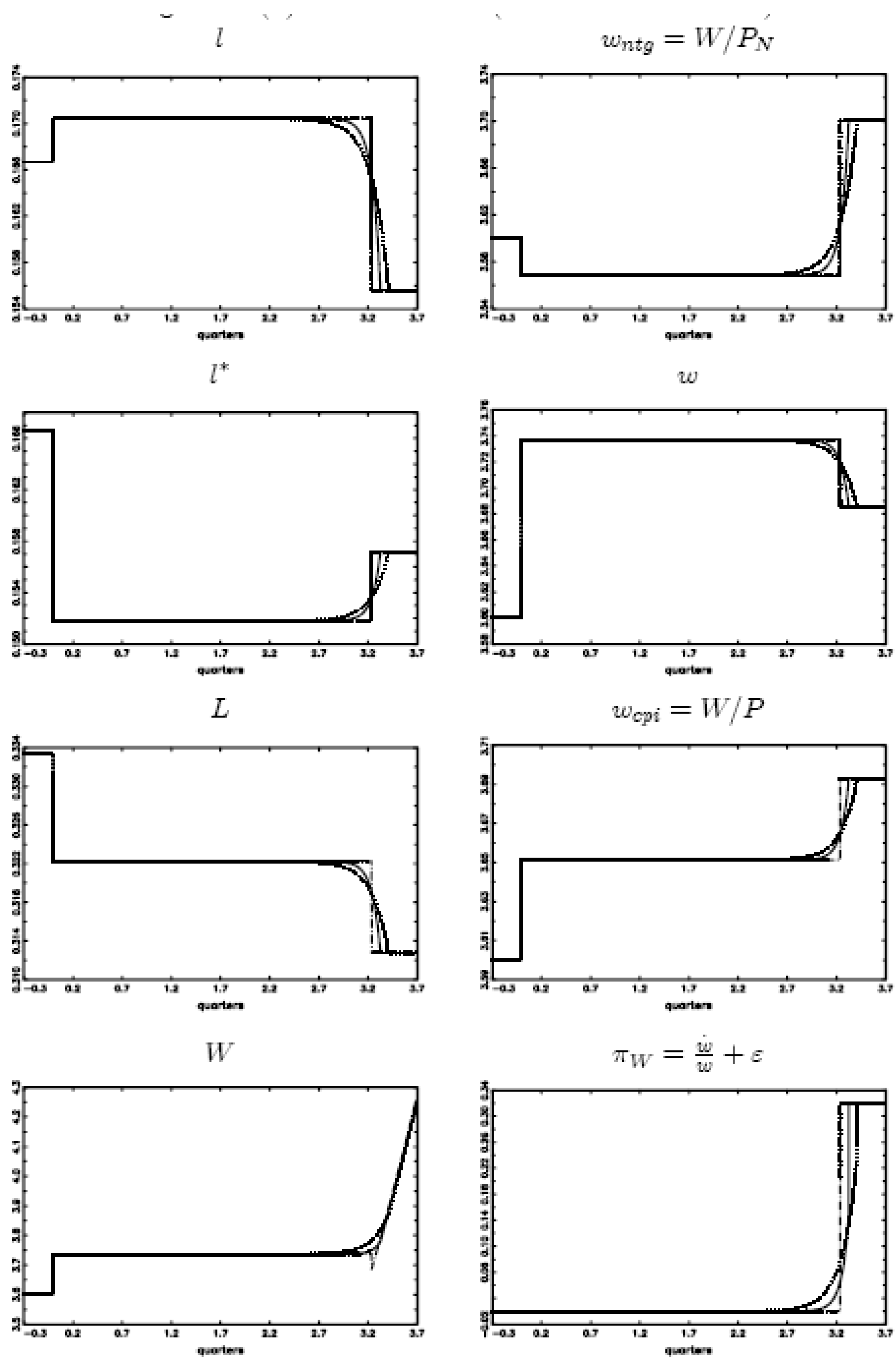


Figure 1: (c) Price Levels and Inflation Rates (Full Accommodation)

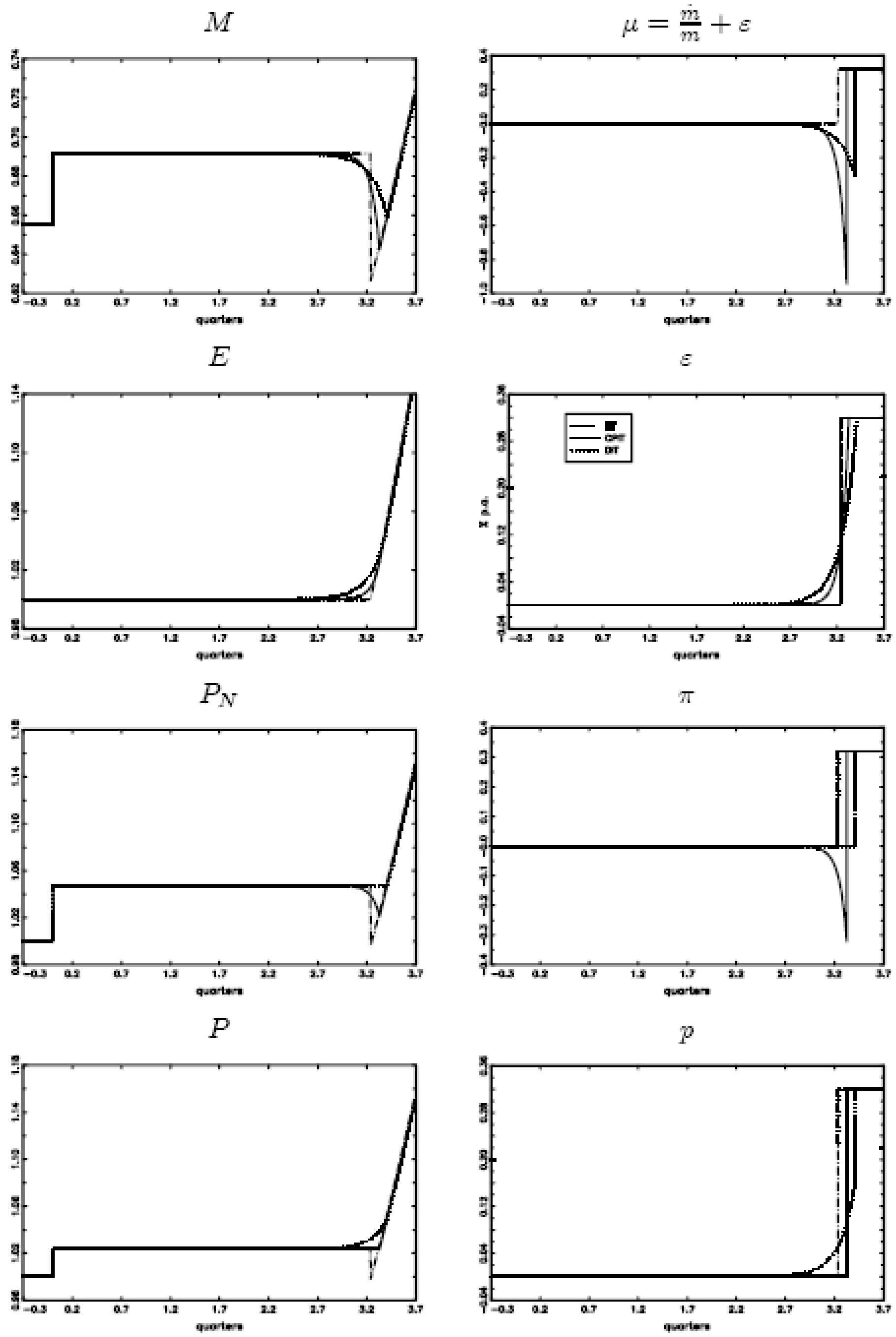
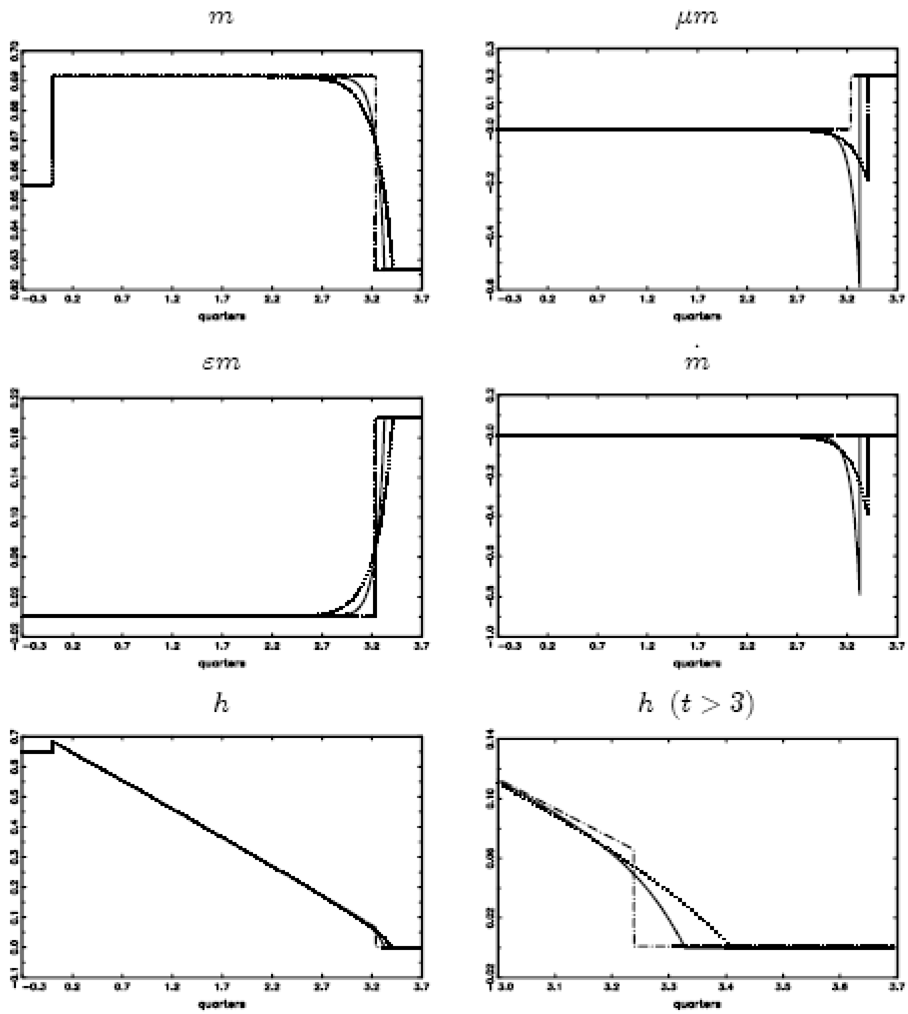


Figure 1: (d) Government Budget (Full Accommodation)



For our baseline case of full monetary accommodation the central bank gains equal reserves in the initial stage of each monetary stabilization program, as it accommodates the increase in real money balances by exchanging nominal money balances against foreign exchange. But as government overspending continues and reserves are depleted, there is upward pressure on exchange rate depreciation under the two inflation targeting regimes.[12] The increasing inflationary distortions lead to a contraction in consumption demand. Because of the lower supply elasticity of nontradables, the economy now experiences a decrease in the relative price of nontradables that makes the collapse in nontradables demand considerably smaller than that in tradables. On the supply side the relative price change draws production and therefore labor demand towards the tradables sector, which helps to eliminate the current account gap that built up during the run-up to the crisis. In the long run both consumption and labor are below their initial steady state values, reflecting not only the foreign asset depletion experienced during the transition but also the higher inflationary distortions in the new steady state, see equation (15).

The differences in the time profiles of real variables between exchange rate and inflation targeting are best understood in terms of the time profiles of these inflationary distortions. By equations (15) and (3) the key variable is the rate of exchange rate depreciation ε_t. Under exchange rate targeting this is held constant by the central bank, both before and, at a different level, after T. There is therefore a discrete increase in distortions and thus in real variables at time T. Under inflation targeting ε_t becomes endogenous, and inflationary distortions are allowed to increase before time T. As a result all real variables approach their post-crisis values in a continuous fashion.

The key question for this paper is the manner in which central bank reserves are depleted. There is, of course, an ongoing depletion due to overspending. But at the same time the collapse in consumption demand towards the end of the inflation targeting regime also leads to a collapse in real money demand. This collapse could take place in two ways, as is made clear by

$$\dot{m}_t = \mu_t m_t - \varepsilon_t m_t \; . \tag{39}$$

Real money balances could drop either through nominal exchange rate depreciation alone ($\varepsilon_t m_t > 0$) or through a deliberate contraction of the nominal money supply ($\mu_t m_t < 0$). Equation (11) suggests that those two effects are substitutes - ceteris paribus, a faster contraction in nominal money balances slows down the depreciation of the nominal exchange rate.[13] The main differences between monetary regimes therefore consist of the degree of commitment to let the money supply contract, or of the degree of commitment against letting the exchange rate depreciate, in order to defend the target of monetary policy. A monetary regime that intervenes less, and lets the exchange rate depreciate earlier and more, thereby collecting a higher inflation tax before the collapse of the regime, suffers smaller reserve losses during the entire transition to the eventual collapse. Its speculative attack is therefore smaller, and given that initial reserves are identical, it takes place later.

We start our detailed discussion of individual regimes with domestic inflation targeting. To simplify the argument, consider money demand equation (12) for the Cobb-Douglas

[12] As discussed in Section 2.5, time T exchange rate depreciation ε_T exceeds zero to finance higher government spending, and furthermore ε_t is continuous for all $t > 0$.

[13] Of course the variables c_t^* and e_t in (11) are endogenous to the monetary regime, but quantitatively the foregoing statement nevertheless turns out to be correct.

case $\sigma = 1$, i.e. $M_t/P_{N_t} = (\alpha/(1-\omega))c_t$. Ceteris paribus the path of c_t, which is given by (8), must decrease as inflationary distortions increase towards the end of the regime. Therefore, at this time a commitment to keep the nontradables price level P_{N_t} unchanged becomes a commitment to contract the nominal money supply by buying foreign exchange. As this intervention happens continuously, it entails flow reserve losses, in other words a flow speculative attack. The monetary contraction reduces the amount of inflation tax $\varepsilon_t m_t$ that can be collected under this regime. We can see in equation (12) that allowing for $\sigma < 1$ as in our calibration produces an effect that goes in the opposite direction, as the real exchange rate depreciation towards the end of the program increases demand for real balances n_t. But quantitatively this latter effect is far smaller than that of contracting consumption demand.[14]

The same effect of a declining consumption path is also present under CPI inflation targeting. But here there is a commitment to intervene that goes even further. To clarify the intuition we again consider the Cobb-Douglas case, for which equation (14) becomes:

$$p_t = \omega\varepsilon_t + (1-\omega)\pi_t \ . \qquad (40)$$

In this case, when exchange rate depreciation picks up there is upward pressure on the CPI inflation rate. Given the zero inflation target for the CPI, it becomes necessary to contract the money supply even further than under domestic inflation targeting. This generates deflation in the nontradables sector in addition to a slowdown in exchange rate depreciation relative to the domestic inflation targeting case. This additional intervention implies that reserves are exhausted more quickly.

The two limiting cases for foreign exchange intervention are exchange rate and money targeting. Under the former, exchange rate pressures are resisted completely by running down reserves. No inflation tax revenue is received before T, $\varepsilon_t m_t = 0$, while the monetary contraction is instantaneous at T, $\frac{M_T - M_{T-}}{E_{T-}} < 0$, rather than continuous, $\mu_t m_t < 0$ for all $t > 0$. The mix between intervention and exchange rate depreciation in (39) is therefore at one extreme, with intervention accounting for 100%. Consequently the reserve losses are the largest and the attack happens most quickly. For money targeting the mix between intervention and exchange rate depreciation is at the other extreme, with depreciation accounting for 100% and no monetary contraction either before or at T. As a consequence exchange rate depreciation under this case starts earliest, and the complete lack of intervention preserves reserves for the longest period possible. Foreign exchange reserves are exhausted only because of government overspending. The common misconception that inflation targeting regimes are not vulnerable to speculative attacks because they represent a 'flexible exchange rate' regime may therefore rest implicitly on the identification of such regimes with money targeting. That however is only correct under very special assumptions. In our model it can be shown to be exactly true under three conditions, the use of domestic (not CPI) inflation targeting, an endowment economy, and Cobb-Douglas preferences.

We have established that inflation targets are in principle vulnerable to speculative attacks, but one can ask whether such attacks are quantitatively significant compared to the exchange rate targeting case. Figure 1 shows that the two inflation targets collapse

[14] In an endowment economy $c_t = y \ \forall t$ the consumption demand effect is not present. In that case the increase in e could lead to an "anti-crisis" where reserves disappear at a decelerating rate towards the end of the program. We thank a referee for pointing this out to us.

later than the exchange rate target. This must be due to a smaller speculative attack, for two reasons. First, the initial reserve position under all three regimes is identical. Second, government deficit related reserve losses per period are equal.

To explore this further we compute the cumulative time T stock equivalent of flow reserve losses under inflation targeting, which equals $\int_0^T \mu_t m_t e^{r(T-t)} dt$, and express it as a fraction of the instantaneous reserve losses under exchange rate targeting for different weights ω of the exchange rate in the price index. The results are presented in Table 1 in the column Reserve Loss Ratio together with results (for the case $\omega = 0.5$) for the timing of the regime collapse T. There are three main findings. First, speculative attacks under inflation targeting are large, equaling at least 45% of the reserve losses under exchange rate targeting. Second, losses under CPI inflation targeting are significantly larger than under domestic inflation targeting. And third, the reserve loss ratio under CPI inflation targeting (and to a lesser extent under domestic inflation targeting) is increasing in ω. The main reason for the last result is that a large tradables share increases the inflationary consequences of any given exchange rate depreciation and therefore forces a larger offsetting monetary contraction. In the limit, as ω goes towards one, CPI inflation targeting approaches exchange rate targeting.

Table 1: Reserve Loss Ratios - Central Bank Accommodates Money Demand at t=0

Regime	ω	Reserve Loss Ratio	T[15]
Exchange Rate Targeting	0.25	1	
	0.5	1	3.2385
	0.75	1	
CPI Inflation Targeting	0.25	0.5421	
	0.5	0.7313	3.3275
	0.75	0.9237	
Domestic Inflation Targeting	0.25	0.4501	
	0.5	0.4809	3.4105
	0.75	0.5204	
Money Targeting	0.25	0	
	0.5	0	3.57[16]
	0.75	0	

We have explored the sensitivity of the above results, by computing results for an endowment economy and for different elasticities of substitution in consumption ($\sigma = 0.5$ and $\sigma = 2$) between tradable and nontradable goods. None of the above conclusions regarding the comparative dynamics of speculative attacks are affected. An endowment economy exhibits somewhat larger differences in crisis timing across regimes.

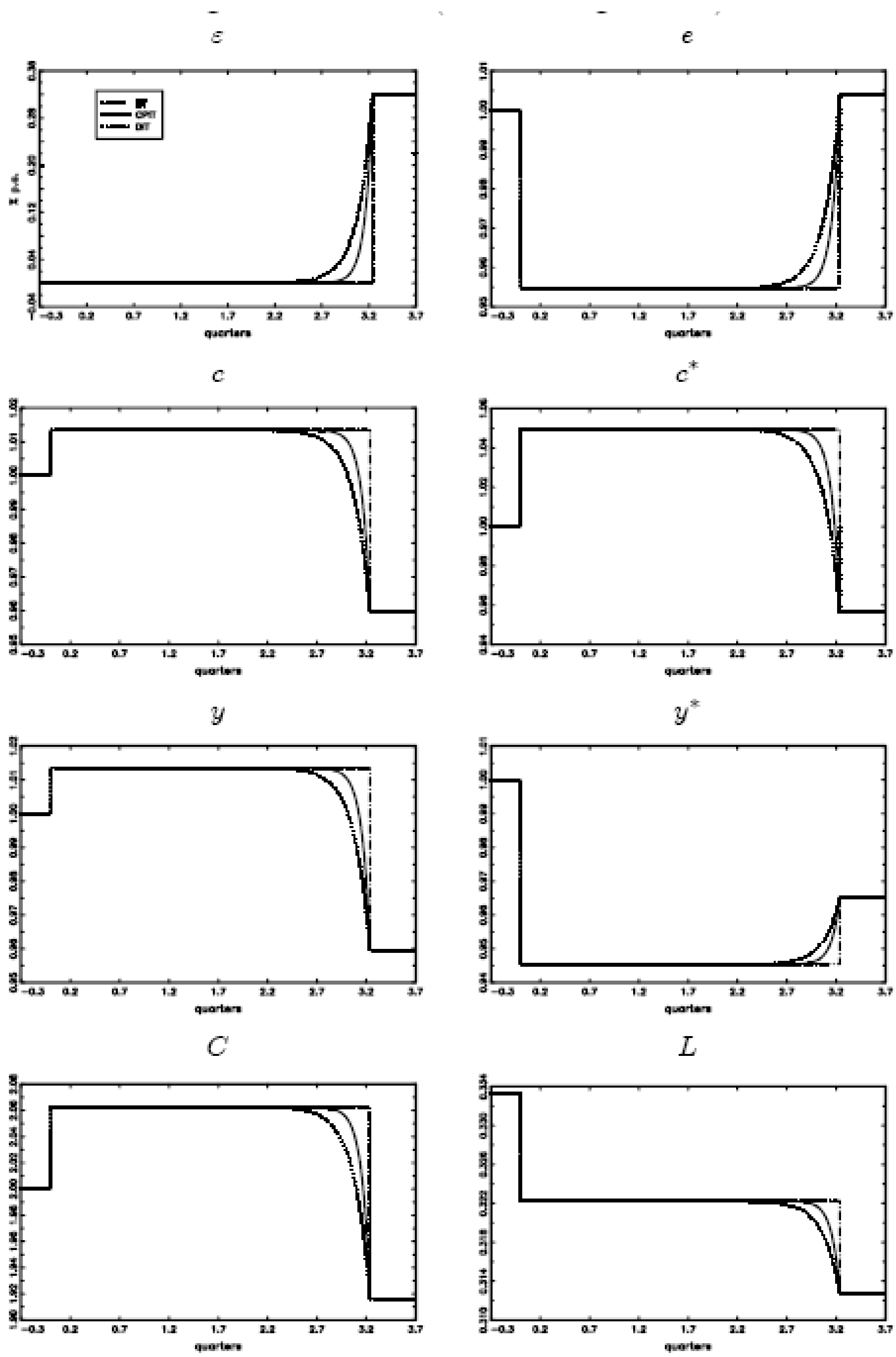
We have also computed solution paths for the case of smooth target paths under the baseline calibration $\omega = 0.5$. Results are shown in Figure 2. A comparison with Figure 1 shows that the main difference concerns initial reserve gains, which are identical for exchange rate targeting, but smaller for CPI inflation targeting, and smaller again for domestic inflation targeting (and zero for money targeting). As a result the differences in crisis timing between exchange rate targeting and either version of inflation targeting are eliminated. This result can be proved analytically for the case of an endowment economy with Cobb-Douglas utility, but in the present case only numerical results, which are shown in Table 2, are available. The reason for this result is that the same factors that protect a monetary regime from reserve losses at the time of collapse (relative to exchange rate targeting) also limit the reserve gains when the policy is first announced. Under exchange rate targeting there is a strong commitment to intervene at time 0 to prevent the increase in real money demand from affecting the exchange rate. Under inflation targeting this commitment is weaker, so that part of the initial increase in real money demand is allowed to lead to a nominal appreciation, with a correspondingly smaller reserve gain. Relative to exchange rate targeting, the smaller interest compounded initial reserve gains offset the smaller subsequent reserve losses during the attack. Given that all remaining reserve losses are due to fiscal spending, which is equal across regimes, the complete depletion of reserves must happen at the same time. Crisis timing for money targeting can be computed directly from the government budget constraint setting $\mu_t m_t = 0$ for $t < T$. For the case of smooth target paths there are neither initial reserve gains nor eventual reserve losses under this regime. It therefore lasts longer, because under all other regimes the initial reserve gain is smaller than the discounted eventual reserve losses, due to the presence of greater distortions in the final steady state.

Table 2: Reserve Loss Ratios - Central Bank Ensures Smooth Target Paths at t=0

Regime	ω	Reserve Loss Ratio	T
Exchange Rate Targeting	0.5	1	3.2385
CPI Inflation Targeting	0.5	0.7473	3.2385
Domestic Inflation Targeting	0.5	0.4895	3.2385
Money Targeting	0.5	0	3.3716

Finally, we briefly compare our results with Mendoza and Uribe (2000, 2001), henceforth MU, who calibrate a model based on the failed Mexican exchange rate based stabilization of 1987-1994. Specification differences between their model and ours include the assumed post-collapse inflation rate (170% versus 32%), the duration of the stabilization program (6 years versus 3 months), a different form of money demand (transactions cost versus cash-in-advance), and a different calibration of money (M2 versus M0). More importantly, MU introduce three attractive theoretical features. The first is an endogenous reduction of government spending during the stabilization, which helps to explain many of its real effects. The second is endogenous capital accumulation that is subject to monetary distortions. And the third is a J-shaped devaluation hazard function, which generates a hump-shaped pattern of real variables rather than the discrete jumps on impact and flat paths seen in the perfect foresight version of MU and in our model. The reason is the time varying tax on savings discussed at the end of Section 2.1.

Figure 2: Overview (Smooth Target Paths)



To compare the welfare results of MU with ours we concentrate on their perfect foresight experiment, where they report a sizeable 5.56% Lucas (1987) compensating variation due to stabilization. They show that more than half of this is due to the wealth effect of lower government spending, and the remainder to the temporary removal of distortions to capital accumulation and, to a much lesser extent, to labor supply. Our model only allows for this last effect, and as a result we find a very small welfare gain of 0.01% for exchange rate targeting.[17] For inflation targeting the welfare gains are almost identical. In the future it would be most interesting to add the model features of MU to our model for a more exhaustive analysis of the dynamics of collapsing inflation targets.

We have shown that under inflation targeting the time varying tax on savings implied by time varying nominal interest rates is at work even under perfect foresight, causing the gradual and then rapid contraction in consumption and money demand that triggers reserve losses. This insight and its quantification are the principal new results of our paper.

B. Two Examples - Chile 1998 and Brazil 2001/2

The case of Chile in 1998 provides a very good illustration of the logic of speculative attacks under inflation targeting. In the first half of 1998 the Chilean Peso was hit by speculative pressure due to the Asian crisis, and from the middle of 1998 by contagion from the Russian crisis. As shown in the top left panel of Figure 3, exchange rate depreciation (year-on-year) immediately began to exceed the inflation target, with actual CPI inflation slightly above its target. The bottom left panel shows the reaction of the central bank - heavy unsterilized foreign exchange intervention with very sizeable reserve losses. The rationale for this policy is stated in Morande and Schmidt-Hebbel (1999): "The Central Bank's peso defense was indeed a defense of the annual inflation target." The evolution of inflation and reserves, and also that of interest rates and output shown in the remaining two panels of Figure 3, are qualitatively consistent with our model, except of course that the defense of the Chilean inflation target was ultimately successful - exchange rate depreciation did not become excessive and the inflation target was met from late 1998 onwards.

Brazil experienced two episodes of speculative pressure in 2001 and 2002, following the adoption of inflation targeting in 1999.[18] The problems in 2001 were due to continued current account imbalances, electricity shortages in June of 2001, and anticipation of the Argentinian default and devaluation at the end of the year. As shown in the top left panel of Figure 4, the result was a large exchange rate depreciation and an incipient deviation from the inflation target for that year. The bottom panel shows the monetary policy response - as in the Chilean case there was heavy foreign exchange intervention and large reserve losses that brought exchange rate depreciation under control. A similar but even more severe episode occurred in 2002, associated with markets' fears about the fiscal

[17] We computed an experiment comparable to MU, by assuming that the initial steady state inflation rate is equal the post-collapse inflation rate under exchange rate targeting. Note that with exogenous labor supply we would observe a welfare loss, as intertemporal consumption substitution effects by themselves are welfare reducing.

[18] See Minella, Springer de Freitas, Goldfajn and Kfoury Muinhos (2003) for a more detailed discussion.

consequences of an increasingly likely, and ultimately realized, victory of da Silva in the October 2002 presidential elections. Exchange rate depreciation and its pass-through to domestic prices were so large in this case that the inflation target was missed by a wide margin. Here the response was twofold, consisting again of heavy intervention and reserve losses, but also of a (temporary) raising of the annual inflation target from 3.5% to 8.5%. The second Brazilian episode, including also the behavior of interest rates and output, bears the closest resemblance to the fiscally driven speculative attack scenario presented in this paper.

V. Conclusion

This paper proposes a general framework to analyze the vulnerability of different monetary regimes to speculative attacks. It thereby fills a gap between the two well-known extremes of exchange rate and money targeting, which exhibit the largest and smallest possible vulnerability to such attacks. For our analysis we choose two different definitions of inflation targeting as the intermediate regimes, inflation targeting currently being the most popular monetary policy choice.

We find that inflation targeting regimes can indeed experience speculative attacks, with the special feature that these are flow attacks that happen over a short period of time rather than instantaneously. This is contrary to the common view of inflation targeting as a flexible exchange rate regime that cannot be attacked. That view relies on the identification of flexible exchange rates with a money targeting regime, which is only correct under very special assumptions. The degree of vulnerability of inflation targeting to attacks, measured either by the speed at which the regime collapses, or by the extent of reserve losses, was shown to lie between the two extremes of exchange rate and money targeting, and to depend on the implicit commitment to intervene in the foreign exchange market. This commitment is relatively higher under CPI inflation targeting than under domestic inflation targeting, and more so if tradable goods account for a larger share of the aggregate consumption basket.

There is an extensive academic literature on the business cycle stabilizing properties of inflation targeting in open economies. This literature concerns the optimization of the performance of inflation targeting in an environment where the basic fiscal prerequisites for a successful monetary policy have been met. This paper analyzes the consequences of those prerequisites not having being met. At least for developing countries this possibility is still highly relevant, and our work should therefore represent a useful complement to the existing literature on open economy inflation targeting.

Figure 3: Chile 1997 - 1999

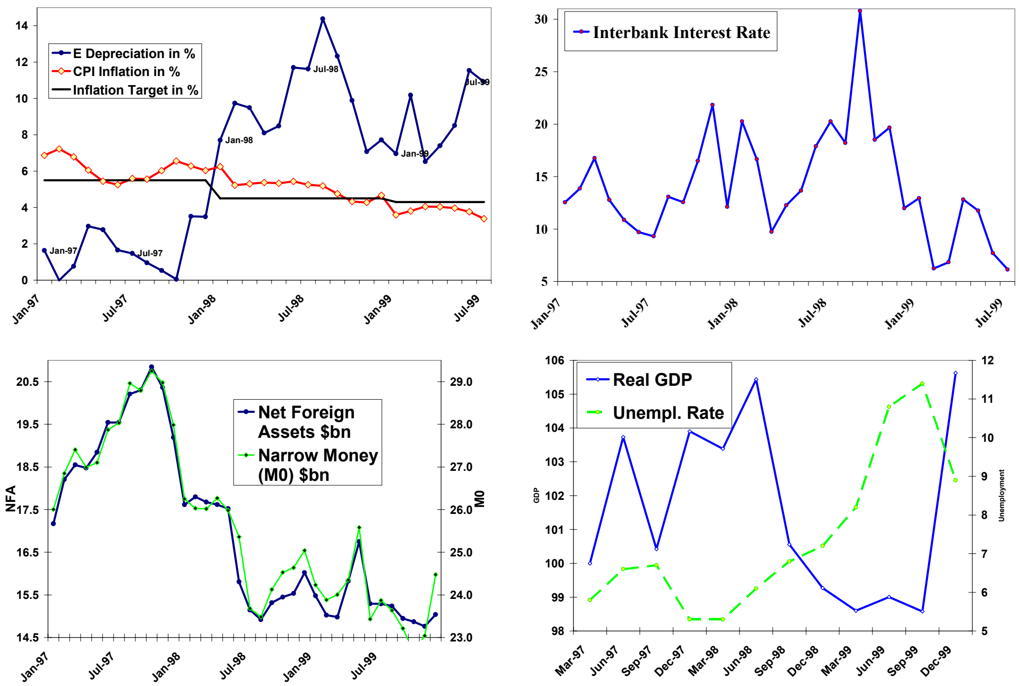
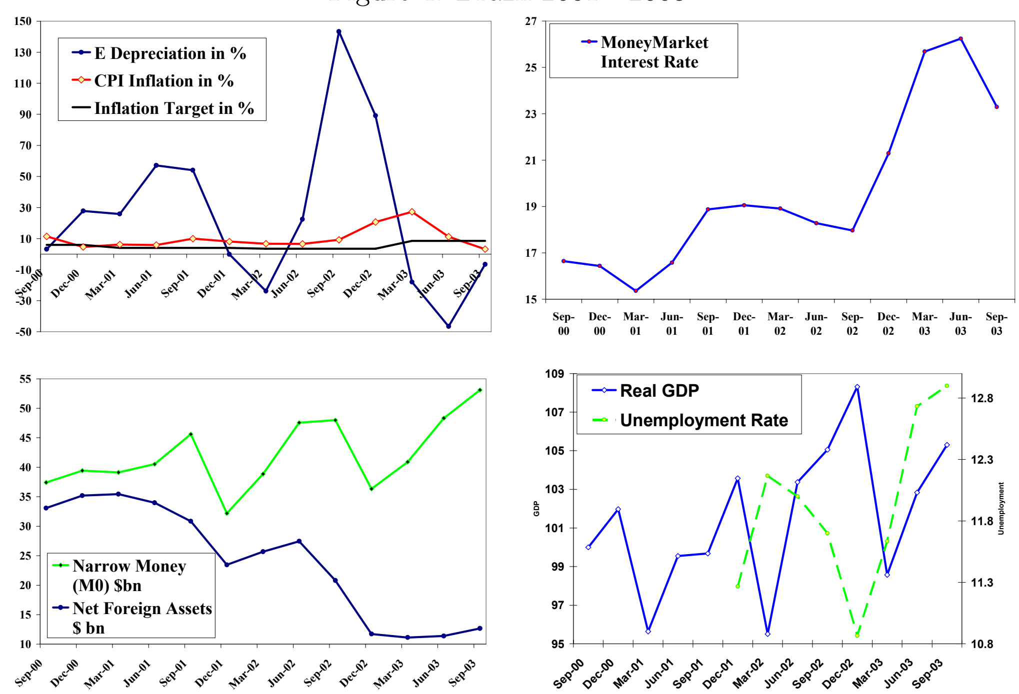


Figure 4: Brazil 2001 - 2003



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