BALANCE OF PAYMENTS CRISES UNDER INFLATION TARGETING

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Abstract

This paper analyzes a small open economy model under a monetary regime that targets the consumer price index. It is explained why such a regime is vulnerable to speculative currency attacks. There are two differences to the exchange rate targeting case: (i) The attack takes place over a short period of time as opposed to instantaneously. (ii) Reserve losses attributable to the attack are smaller, and increasing in the share of tradable goods in total consumption. Furthermore, it is shown that targeting domestic (nontradables) inflation would completely eliminate speculative attacks.

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

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1 INTRODUCTION

This paper analyzes a small open economy model under a monetary regime that targets the consumer price index (CPI). It is explained why such a regime, henceforth referred to as CPI inflation targeting, is vulnerable to speculative currency attacks. Some important differences between such attacks and balance of payments crises under exchange rate targeting are highlighted. It is also shown that, if it were practically feasible, targeting nontradables inflation, henceforth referred to as domestic inflation targeting, would completely eliminate speculative attacks. The theoretical point is general, but it appears 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, Spain, 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 et al. (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 this is not correct if a workable definition of the target variable is adopted, and if the policymaker is fully committed to that target. The reason is very intuitive, but it appears to have been overlooked by the literature and by many policymakers, as we will show below with some examples. It is that in an open economy the exchange rate is a very important determinant of the CPI, and that therefore some exchange rate management is necessary to meet a CPI inflation target. This implies a commitment to intervening in the foreign exchange market if necessary, and that commitment in turn makes a speculative attack possible.

We choose as our expository device a simple but fully microfounded balance of payments crisis model related to Calvo (1987). This is a 'first generation' model and uses an endowment specification of goods supply to keep the analysis tractable. Extensions to more general specifications of supply would alter some of the more specific quantitative conclusions at the end of the paper, but they would not alter the two key results: CPI

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

inflation targeting does provide a channel through which a currency can be attacked, and the size of that attack is intermediate between exchange rate and domestic inflation targeting. Extensions to second generation speculative attacks are also 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 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. The Brazilian crisis of 1999 is only the most recent example of an exchange rate collapse driven by unsustainable fiscal policies.

Our model includes both tradable and nontradable goods, which allows a natural specification of the consumer price index. As documented extensively in International Monetary Fund (2000), this is the variable targeted in all current inflation targeting regimes.

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[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 3.

It is shown that once reserves are sufficiently low due to overspending, exchange rate depreciation starts to exceed the CPI inflation target in anticipation of the crisis. To continue to meet the target the central bank has to contract the money supply, which generates domestic (nontradables) deflation and thereby keeps the CPI on target. But this foreign exchange intervention also generates sharply accelerating flow reserve losses in the final phase of the program. In numerical experiments this final phase is short but, unlike a collapsing exchange rate target, not instantaneous.

We go on to show that a greater weight of the exchange rate in the nominal target variable implies greater vulnerability to speculative attacks. For an open economy which targets the CPI inflation rate this weight is well above zero. This has important consequences for monetary policy in small open economies. The only way to completely rule out speculative attacks is to choose a target which does not involve any commitment to central bank intervention in the foreign exchange market. One possibility is to target domestic inflation. This conclusion gives further support to 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]

At the same time, it should be pointed out that strict domestic inflation targeting is

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[3] See Gali and Monacelli (2002) for a statement of this case. However, Smets and Wouters (2002) show that that result depends on specific assumptions about the number of sectors and the sectoral incidence of nominal rigidities.

[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.

rarely if ever used in practice, particularly in emerging markets, even if some version of 'core inflation' targeting may get somewhat closer to that theoretical notion than CPI targeting. This is not only because many of these countries have a history of price index manipulations, which makes a well understood index such as the CPI preferrable for credibility reasons. There are also formidable practical difficulties in constructing the correct empirical counterpart of the theoretical notion of a nontradables price index in a world where almost all goods have at least some foreign input component.

The rest of the paper is organized as follows. Section 2 develops the model. Section 3 assigns parameter values and discusses the solutions. Section 4 concludes.

2 THE MODEL

Consider a small open economy which consists of a government and representative, price-taking, infinitely-lived consumers. Lower/upper case letters represent real/nominal quantities. For tradable goods, purchasing power parity holds[5] and their international price is constant and normalized to one. Nontradable goods prices are flexible.

Consumers

Consumers maximize lifetime utility derived from the consumption of tradable goods c_t^* and nontradable goods c_t. Their personal discount rate equals the constant real international

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[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).

interest rate r. The objective function is

$$Max \quad \int_0^\infty (\gamma \ln c_t^* + (1-\gamma) \ln c_t)\, e^{-rt} dt \ , \tag{1}$$

i.e. the consumption aggregator is $C_t = c_t^{*\gamma} c_t^{1-\gamma}$. Consumers receive fixed endowments of tradables and nontradables y^* and y, and government lump-sum transfers g_t. The nominal exchange rate and the price level of nontradables are denoted by E_t and P_{N_t} respectively, and the relative price of tradables by $e_t = E_t/P_{N_t}$. Consumers hold two types of assets, real international bonds b_t and real money balances $m_t = M_t/E_t$, with total asset holdings $a_t = b_t + m_t$. Real money balances in terms of nontradable goods are $n_t = M_t/P_{N_t}$. The rate of currency depreciation is denoted by $\varepsilon_t = \dot{E}_t/E_t$, and uncovered interest parity is assumed to hold:

$$i_t = r + \varepsilon_t \ . \tag{2}$$

Consumers face the following flow budget constraint in terms of tradables:

$$\dot{b}_t = rb_t + y^* + \frac{y}{e_t} + g_t - c_t^* - \frac{c_t}{e_t} - \dot{m}_t - \varepsilon_t m_t \ . \tag{3}$$

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

$$a_0 + \int_0^\infty \left(y^* + \frac{y}{e_t} + g_t \right) e^{-rt} dt \geq \int_0^\infty \left(c_t^* + \frac{c_t}{e_t} + i_t m_t \right) e^{-rt} dt \ . \tag{4}$$

There is a cash-in-advance constraint on consumption

$$m_t \geq \alpha \left(c_t^* + \frac{c_t}{e_t} \right) \ , \tag{5}$$

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 (see Appendix A). The consumer's problem is to maximize (1) subject to (4) and (5), with (5) binding, taking as given $\{y_t^*, y_t, g_t, r_t, E_t, P_{N_t}\}_{t=0}^{\infty}$. The first-order conditions, apart from (4) holding with equality, are

$$c_t^* = \frac{c_t}{e_t}\frac{\gamma}{1-\gamma} \ , \tag{6}$$

$$\frac{\gamma}{c_t^*} = \lambda(1+\alpha i_t) \ . \tag{7}$$

Equation (6) can be combined with (5) to derive expressions for real money balances:

$$m_t = \alpha c_t^* \gamma^{-1} \ , \tag{8}$$

$$n_t = \alpha c_t (1-\gamma)^{-1} \ . \tag{9}$$

Defining $\mu_t = \dot{M}_t/M_t$, equation (8) implies $\dot{m}_t/m_t = (\mu_t - \varepsilon_t) = \dot{c}_t^*/c_t$.

Definition of the CPI Inflation Rate

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:

$$P_t = E_t^{\gamma} P_{N_t}^{1-\gamma} \gamma^{-\gamma} (1-\gamma)^{-(1-\gamma)} \ . \tag{10}$$

Letting $p_t = \dot{P}_t / P_t$ and $\pi_t = \dot{P}_{N_t} / P_{N_t}$ we also have

$$p_t = \gamma \varepsilon_t + (1 - \gamma) \pi_t \ . \tag{11}$$

Government

The government's policy consists of a specification of the path of lump-sum transfers $\{g_t\}_{t=0}^{\infty}$, and of the initial target path for the level of its nominal anchor, which is fully described by an initial condition and a constant slope. A target for the growth rate of the nominal anchor alone, as is well known, is insufficient for price-level determinacy. The target growth rate of the nominal anchor is assumed to be unsustainably low initially given the path of transfers $\{g_t\}_{t=0}^{\infty}$. Initial targets are $\bar{p}$ for CPI inflation targeting, $\bar{\varepsilon}$ for exchange rate targeting, and $\bar{\pi}$ for domestic inflation targeting. The eventual steady state growth rate of the nominal anchor will be determined by a balanced budget requirement for the government. 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. We will comment on two different cases in Section 3.

We specify monetary policies as setting target paths for nominal price level variables, and as using the nominal money supply as the instrument of monetary policy. This has advantages for analytical tractability. But in addition, the alternative of specifying an interest rate rule with feedback to inflation deviations is known to suffer from indeterminacy problems in an open economy and under flexible price setting.[6] Taylor (2000) suggests that in emerging markets a monetary aggregate may in fact be preferable as the instrument of monetary policy, because under the high and variable risk premia characterizing these economies there may be uncertainty about the equilibrium real interest rate.

Let h_t be the government's foreign exchange reserves. Then its flow budget constraint is

$$\dot{h}_t = rh_t + \dot{m}_t + \varepsilon_t m_t - g_t \ . \tag{12}$$

At times of discrete jumps in nominal money balances between t^- and t the following must hold for foreign exchange reserves:

$$h_t - h_{t^-} = (M_t - M_{t^-})/E_{t^-} = dM_{t^-}/E_{t^-} \ . \tag{13}$$

There is a minimum level of net foreign assets, which for simplicity will be assumed to be equal to zero:[7]

$$h_t \geq 0 \quad \forall t \ . \tag{14}$$

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 (12) as follows:

$$h_0 + \int_0^\infty i_t m_t e^{-rt} dt = m_0 + \int_0^\infty g_t e^{-rt} dt \ . \tag{15}$$

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[6] See Benhabib et al. (2001) for a very general statement of the indeterminacy result in a closed economy. In an open economy with nominal rigidities, Parrado and Velasco (2002) recover determinacy by having interest rates respond to price level deviations instead of inflation deviations.

[7] See Obstfeld (1986b) 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.

Equilibrium and Balance of Payments

A *government policy* is defined as a list of time paths $\{P_t, g_t\}_{t=0}^{\infty}$ under CPI inflation targeting, $\{E_t, g_t\}_{t=0}^{\infty}$ under exchange rate targeting and $\{P_{N_t}, g_t\}_{t=0}^{\infty}$ under domestic inflation targeting such that, given a list of time paths $\{m_t, E_t, r_t\}_{t=0}^{\infty}$ under CPI inflation targeting and domestic inflation targeting, and $\{m_t, r_t\}_{t=0}^{\infty}$ under exchange rate targeting, the conditions (13), (14) and (15) hold for all t. An *allocation* is a list of time paths $\{b_t, h_t, m_t, c_t^*, c_t, y_t, y_t^*\}_{t=0}^{\infty}$, and a *price system* is a list of time paths $\{E_t, P_{N_t}, r_t\}_{t=0}^{\infty}$ under CPI inflation targeting, $\{E_t, r_t\}_{t=0}^{\infty}$ under domestic inflation targeting, and $\{P_{N_t}, r_t\}_{t=0}^{\infty}$ under exchange rate targeting. Finally let $f_t = b_t + h_t$, the economy's overall net foreign assets. Then the equilibrium is defined as follows:

A perfect foresight equilibrium given f_0 is an allocation, a price system, and a government policy such that (a) given the government policy and the price system, the allocation solves the household's problem of maximizing (1) subject to (4) and (5), with (5) binding, (b) the nontradable goods market clears at all times, $c_t = y \ \forall t$.

Combining (4) and (15) the economy's overall resource constraint can then be derived as

$$f_0 + \frac{y^*}{r} = \int_0^{\infty} c_t^* e^{-rt} dt \ , \tag{16}$$

with current account $\dot{f}_t = r f_t + y^* - c_t^*$. Finally nontradables market clearing, from (9), implies $\mu_t = \pi_t \ \forall t$. Therefore domestic inflation targeting is equivalent to money targeting in this model.

Balance of Payments Crisis

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

$$g_I = rh_I \ . \tag{17}$$

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[8] while government transfers g are permanently increased from g_I to $\bar{g}$, where $\bar{g} > rh_I$. By (12) this generates a gradual and ultimately complete depletion of foreign exchange reserves, so that within finite time T the constraint (14) becomes binding and the economy reaches its final (subscript T) steady state. The time T is endogenous. Given that the constraint (14) is binding for all $t \geq T$, the budget must be balanced through higher seigniorage income from that time onwards:

$$\bar{g} = \varepsilon_T m_T \ . \tag{18}$$

Given (8), final steady state inflation $p_T = \varepsilon_T = \pi_T$ is therefore given by $p_T = \gamma\bar{g}/\left(\alpha(y^* + rf_T)\right) > 0$.

The features of balance of payments crises under exchange rate targeting are well-known from the literature. It is also clear that under domestic inflation targeting reserves will be

[8] This involves no loss of generality but greatly simplifies the computations, see Appendix A.

depleted through government spending alone. An attack on reserves is impossible because the central bank is committed to not intervening in the foreign exchange market.[9] Under CPI inflation targeting, the government's rule for the growth rate of the domestic price level π_t and therefore for the growth rate of the nominal money supply μ_t is, given the inflation target, a function of ε_t by (11). The system can therefore be written in terms of ε_t given an exogenous p_t. To do so, first differentiate the first-order condition (6) and combine it with (11) to get

$$\frac{\dot{c}_t^*}{c_t^*} = \frac{1}{1-\gamma}(p_t - \varepsilon_t) \ . \tag{19}$$

When first-order condition (7) is differentiated and combined with (19) we obtain

$$\dot{\varepsilon}_t = \frac{1+\alpha i_t}{\alpha(1-\gamma)}(\varepsilon_t - p_t) \ . \tag{20}$$

The following argument shows that under CPI inflation targeting both c_t^* and ε_t must be continuous for all $t > 0$ including T. The path of E_t must be continuous to rule out arbitrage opportunities, and the path of P_t is continuous by the inflation targeting policy. By (10) this means that the path of P_{N_t} is also continuous, and therefore so is $e_t = E_t/P_{N_t}$. From the definition of equilibrium we have that $c_t = y \, \forall t$. Taken together with (6) these results imply that c_t^* is continuous, which by (2) and (7) implies continuity of ε_t.

Figure 1 shows the dynamic system (19) and (20) linearized around $\bar{\varepsilon} = 0$ and different values of c^*. This system has one zero and one positive eigenvalue. It is characterized by a linear center manifold at $\bar{p} = 0$ and a continuum of unstable paths. Both ε_t and c_t^*

[9] Except possibly once at $t = 0$ in the case of full monetary accommodation.

are free or jump variables, but the lifetime path of c_t^* is nevertheless constrained by the intertemporal resource constraint (16). As shown in Appendix A, this and the economy's optimality conditions is sufficient to determine both the initial jumps and the time paths of both variables. In Section 3 we will show that a typical solution path, ignoring nonlinearities, is represented by A-B-C.

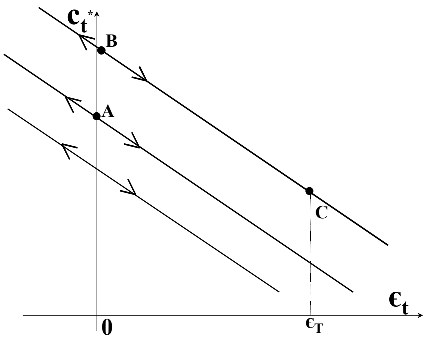

Figure 1

3 Model Solution

Parameter Values

Parameter values are assigned in accordance with Table 1. The time unit for calibration of stock-flow ratios is a quarter. Where available, parameters are based on Brazilian data, Brazil being one of the first emerging economies to adopt inflation targeting. For an emerging market 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 has mostly fluctuated between 10% and 15%, which after adjusting for US inflation suggests using r = 10%. The inverse velocity

α is set equal to the ratio of real monetary base to quarterly absorption in Brazil in 1996. A 50% share of tradables in consumption (γ) is empirically reasonable, see De Gregorio, Giovannini and Wolf (1994). The nontradables and tradables endowments are normalized to 1. This yields a normalized initial level of quarterly real GNP of 2. The parameters α and γ imply $m_I = 0.6$. Central bank foreign exchange reserves h_I are set at 0.8, based on the h/m-ratio in Brazil in 1996.

Parameter	**Value**	**Description**
p_I	0% p.a.	Initial inflation target
$\bar{p}$	0% p.a.	New inflation target
————	————	————————————
g_I	0.02	Initial government transfers
$\bar{g}$	0.20	New, permanently higher
		government transfers
————	————	————————————
h_I	0.8	Initial reserves
f_I	0	Initial net foreign assets
————	————	————————————
r	10% p.a.	Real international interest rate
β	10% p.a.	Subjective discount rate
α	0.3	Inverse velocity
γ	0.5	Share of tradable goods
y	1	Nontradables endowment
y^*	1	Tradables endowment

Table 1: Parameter Values

Appendix A shows how the solution paths of all variables are computed. It also shows that the solutions are locally unique. Solution paths for CPI inflation targeting (CPIT) are presented as the solid lines in Figure 2 below and compared to exchange rate targeting (ET, broken lines) and domestic inflation targeting (DIT, bold solid lines).[10]

[10] The exchange rate targeting case is straightforward to compute, and the method for the money targeting

Dynamics of the Speculative Attack

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. This could take several forms. The least plausible today, even in emerging markets, is old-fashioned money printing, the money being immediately returned to the central bank in exchange for foreign bonds. More likely it would take the form of issuing bonds, which would however have the same effect on the net foreign asset position. The fact that inflation will be higher in the future leads households to engage in intertemporal substitution - by (7) 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.

To derive the exact time paths of the key variables, an additional assumption must be made about the behavior of the monetary authority at time 0, when it is faced with a sudden increase in real money demand. To satisfy this demand, it could choose to increase nominal money balances, to keep nominal balances unchanged and let the exchange rate appreciate, or various combinations of the two. This has repercussions for the initial level of foreign exchange reserves, which only increase to the extent that money is issued in exchange

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case is very similar to that for inflation targeting. We therefore omit the detail for these cases in Appendix A.

for foreign assets, thereby generating one-off seigniorage revenue of dM_t/E_t. We assume that the increase in real money demand is fully satisfied through money issuance, thereby increasing reserves by nearly equal amounts on impact under all regimes[11] while keeping the exchange rate constant. As a result there are discontinuous jumps in P_{N_t} by (9) and therefore in P_t by (10). This assumption is not only quite plausible[12], it also has the advantage of eliminating differences in initial reserves as a source of differences in crisis timing.

One alternative, discussed in more detail in Appendix B, would be to assume that the respective target paths of E_t, P_{N_t} or P_t are continuous at all times. Under domestic inflation targeting this would, by (9) and (10), imply a large exchange rate appreciation, no monetary accommodation and therefore no initial reserve gains. Under CPI inflation targeting it would imply smaller reserve gains than under full monetary accommodation. Appendix B shows that these smaller initial reserve gains across regimes are matched by their smaller speculative attacks in such a way that the final collapse time of all monetary regimes is identical.

The final collapse of each monetary regime is associated with higher nominal interest rates and therefore a collapse in real money demand by (7) and (8). Under exchange rate targeting this happens as an instantaneous speculative attack. The reduction in real money balances is accomplished through an exchange for the remaining stock of central

[11] There are some negligible differences in the initial jumps in real money demand between regimes.

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

bank foreign exchange reserves. In the remaining two cases the increase in the nominal interest rate is not abrupt, but it is nevertheless concentrated in a short period before the final collapse of the regime. Under domestic inflation targeting the central bank's foreign exchange reserves are not accessible to speculators. Because the exchange rate is flexible the entire collapse in real money balances happens through accelerating depreciation, and foreign exchange reserves are depleted through spending alone. The CPI inflation targeting case is intermediate. As under domestic inflation targeting, the increases in the nominal interest rate and exchange rate depreciation begin immediately. However, this tends to drive the CPI inflation rate up. The central bank is then forced to allow a steady monetary contraction which generates offsetting domestic deflation and keeps the CPI on target. Unlike in the domestic inflation targeting case the collapse in real money balances is therefore only partly accomplished through exchange rate depreciation, the other part being attributable to central bank intervention in the foreign exchange market in order to engineer the monetary contraction. As this intervention happens continuously, it entails flow reserve losses, in other words a flow speculative attack. The key to understanding this is the seigniorage term in the government's budget constraint, which is shown as the bottom left panel of Figure 2:

$$\dot{m}_t + \varepsilon_t m_t = \mu_t m_t = \pi_t m_t \ . \tag{21}$$

Although there may be an increase in the inflation tax component of seigniorage $\varepsilon_t m_t$ in the final stages of the program, the nominal interest rate rises so fast and therefore money demand falls so fast that overall seigniorage declines steeply, thereby accelerating reserve losses above those caused by the primary deficit $\bar{g}$. The total amount of reserve losses is represented by the triangular area above the seigniorage curve and below 0 in the last panel.

The dynamics generated by collapsing exchange rate and CPI inflation targets look quite similar. Although under inflation targeting reserve losses due to foreign exchange market intervention occur as flows, almost all losses are concentrated in about one month before the end of the program. The reason, as shown in Appendix A, is that exchange rate depreciation follows a nonlinear first-order differential equation such that it starts very close to zero but then accelerates at an increasing rate. By equations (2), (5), (6) and (7) this implies an accelerating decrease in money demand.

We have established that CPI 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 2 shows that the CPI inflation target collapses later than the exchange rate target but earlier than the domestic inflation target. This must be due to a smaller speculative attack, for two reasons. First, the initial reserve position under all three regimes is nearly identical. Second, government deficit related reserve losses per period are equal.

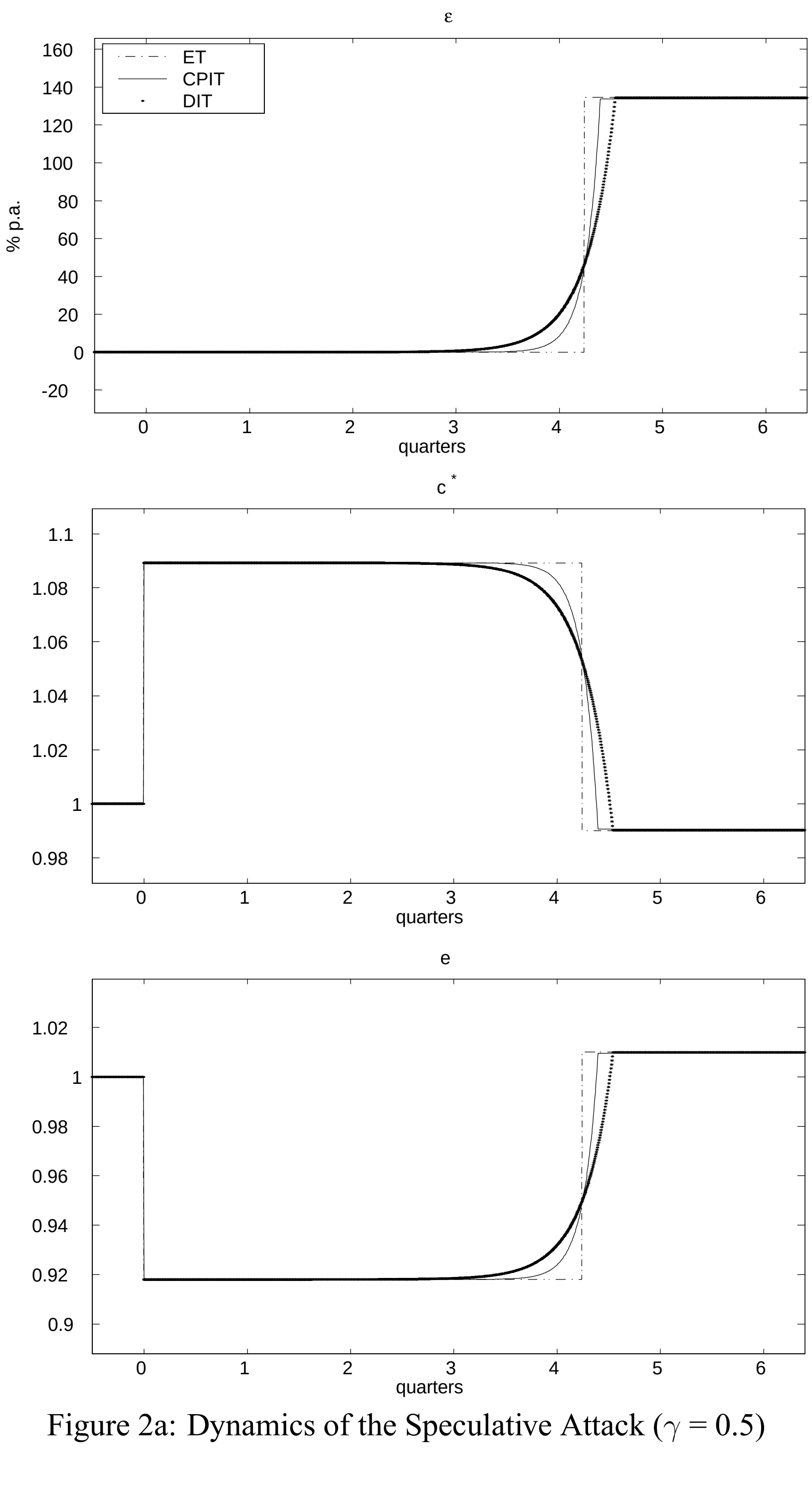

Figure 2a: Dynamics of the Speculative Attack ($\gamma = 0.5$)

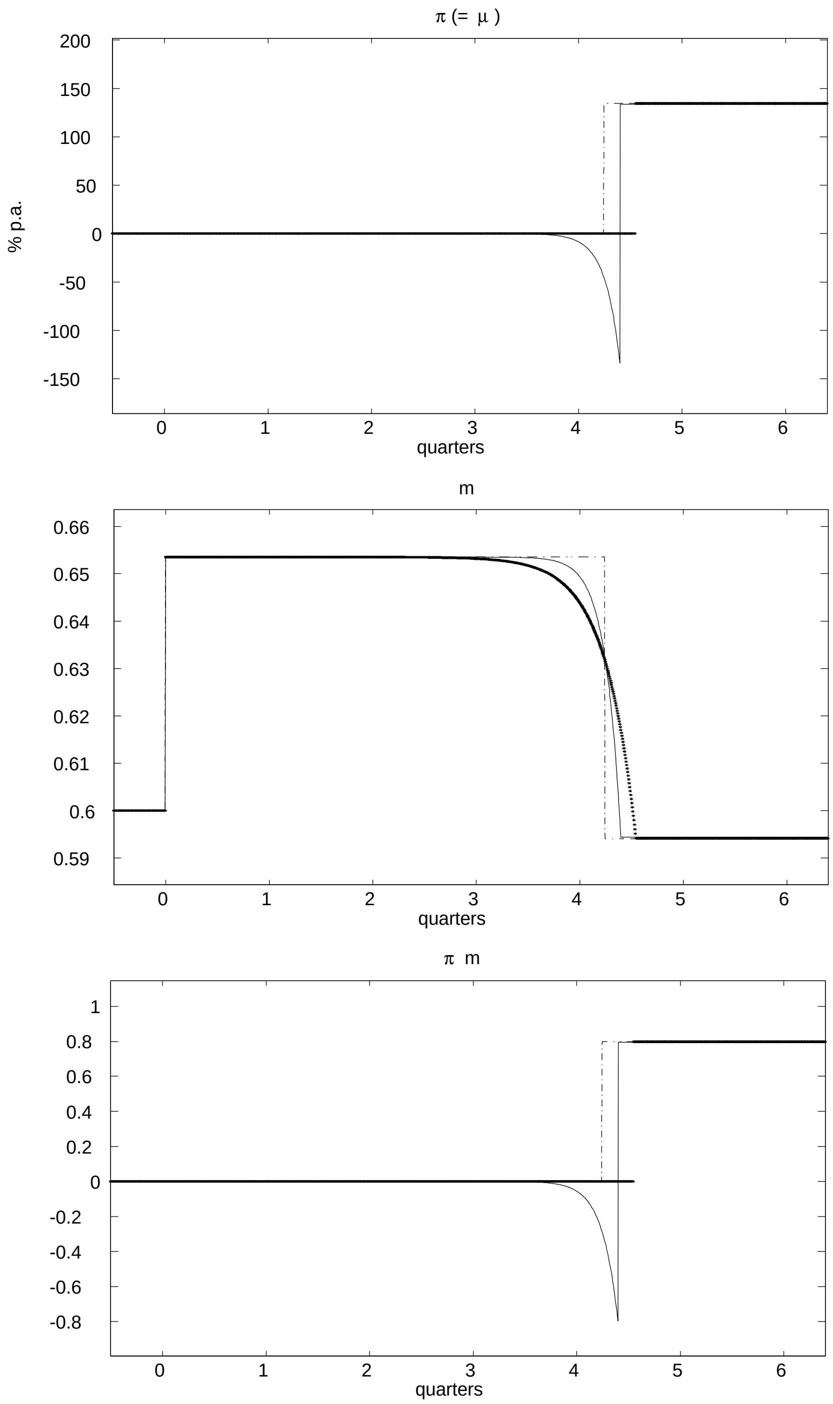

Figure 2b: Dynamics of the Speculative Attack ($\gamma = 0.5$)

To explore this further we compute the cumulative time T stock equivalent of flow reserve losses under inflation targeting, which equals $\int_0^T \pi_t m_t e^{r(T-t)} dt$, and express it as a fraction of the instantaneous reserve losses under exchange rate targeting for different weights γ of the exchange rate in the price index. The results are presented in Table 2 in the column Reserve Loss Ratio together with results for the timing of the regime collapse T.[13] We find that this fraction is increasing in γ and in fact very close to γ. The lesson is that vulnerability to a speculative attack increases with the weight of the exchange rate in the target variable of monetary policy. Under inflation targeting that weight is lower than under exchange rate targeting, but it is well above zero.[14]

MONETARY REGIME	γ	T	**RESERVE LOSS RATIO**
Domestic Inflation Targeting	**any**	4.54	0%
CPI Inflation Targeting	**0.2**	4.48	19%
	0.3	4.45	30%
	0.4	4.43	38%
	0.5	4.40	48%
	0.6	4.37	58%
	0.7	4.34	68%
	0.8	4.31	76%
Exchange Rate Targeting	**any**	4.24	100%

Table 2 : Crisis Timing and Reserve Losses

[13] We also computed Lucas (1987) compensating variation welfare losses. Given the flexible price assumption and the absence of financial market repercussions of an exchange rate collapse in our model, these losses were invariably well below 0.1%.

[14] While the time profiles of economic variables do depend on γ under exchange rate targeting and domestic inflation targeting, the reserve loss ratio and crisis timing do not.

An Example - Chile 1998

The case of Chile in 1998 provides an almost perfect illustration of the logic of speculative attacks under inflation targeting.[15] 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 panel of Figure 3, exchange rate depreciation (year-on-year) immediately began to exceed the inflation target, with the actual CPI slightly above its target. The bottom 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 (2000): "The Central Bank's peso defense was indeed a defense of the annual inflation target." This defense was successful, exchange rate depreciation did not become excessive and the inflation target was met from late 1998 onwards.[16]

A reading of Latin American central bank publications on inflation targeting at that time shows that several of them did not demonstrate an awareness of the possibility of speculative pressure or attacks under inflation targeting. See for example Tombini and Bogdanski (2000) for Brazil, and Uribe, Gomez and Vargas (2000) for Colombia who do not mention the issue at all. Carstens and Werner (1999), for Mexico, state that policymakers have found that they

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[15] The Chilean attacks were driven by contagion, but as mentioned in the introduction the logic of our argument is independent of the source of the speculative attack.

[16] We computed the tradables share in Chilean final consumption on the basis of 1996 national accounts data as 45.6%. The sectors defined as tradables for this purpose are agriculture, forestry, fishing, mining and manufacturing.

must at times allow large shocks to the exchange rate to lead to temporary deviations from the inflation target. In that case the commitment to the inflation target is contingent on the absence of speculative pressure. This may be a point of concern, because credibility of the commitment to the nominal anchor continues to be a much more critical issue for monetary policy in emerging markets than it is in advanced economies.[17]

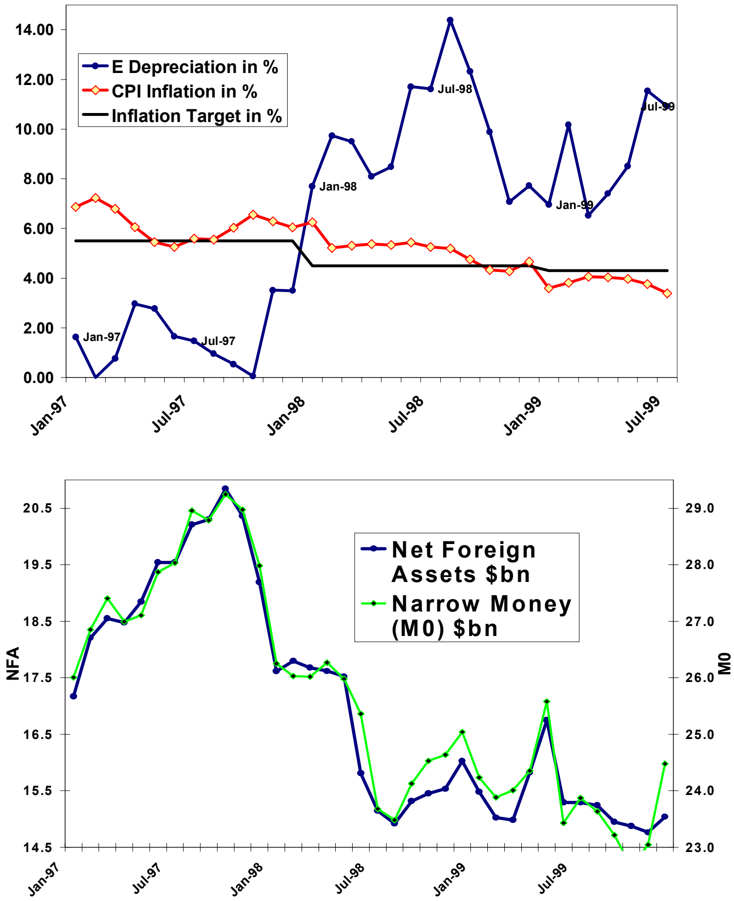

Figure 3: Chile 97-99

[17] More recently, in the run-up to the 2002 presidential election, Brazil also experienced some net reserve losses in an attempt to defend the Real and thereby its inflation target. Part of this took the form of issuing additional dollar-denominated central bank debt.

4 Conclusion

Inflation targeting is a commitment on the part of the monetary policymaker to achieve a certain path or target range of the consumer price index. Given that in a small open economy this index is strongly influenced by the exchange rate, and given that targeting a purely 'domestic' price index is in practice very difficult, foreign exchange market intervention becomes a necessary part of monetary policy. This makes balance of payments crises possible. This paper has shown that such crises have quite similar dynamics to the collapse of a fixed exchange rate regime, with two important exceptions. One is that the attack takes place over a short time period as opposed to instantaneously. The other is that reserve losses attributable to the attack are smaller, and increasing in the share of tradable goods in total consumption.

Therefore if one places inflation targeting on an equal footing with exchange rate targeting by assuming an equally strict commitment to the target (see the Chilean example), qualitatively very similar channels for a speculative attack exist under both regimes. The main differences are quantitative. This problem is clearly a very important one for the new generation of inflation targeters in emerging markets, because their fiscal situations are generally far less robust than those of the first generation in industrialized countries.

Appendix A

We describe the method used to compute the model's equilibrium paths, and we demonstrate that these paths are locally unique. We concentrate on the case of full monetary accommodation, the argument for the strict levels targeting case is almost identical. Equation (20) determines the complete dynamic path $\{\varepsilon_t\}_{t=0}^{\infty}$ once an initial condition ε_0 and the length of the transition period T are known. The solution to (20) is

$$\varepsilon_t = \frac{B\varepsilon_0}{e^{-Bt}[B + A\varepsilon_0] - A\varepsilon_0}\ , \tag{A.1}$$

where $A = 1/(1-\gamma)$ and $B = (1+\alpha r)/(\alpha(1-\gamma))$. Given this path, equations (7) and (16) can be used to determine λ:

$$\lambda(\varepsilon_0, T) = \frac{1}{f_0 + \frac{y^*}{r}} \left\{ \int_0^T \frac{\gamma}{1+\alpha r + \alpha\varepsilon_t} e^{-rt} dt + \frac{\gamma}{1+\alpha r + \alpha\varepsilon_T} \frac{e^{-rT}}{r} \right\}\ . \tag{A.2}$$

It can be verified that all other variables can be computed from (A.1) and (A.2). The key for the computation of equilibrium paths is therefore the determination of ε_0 and T. Note first that we can restrict attention to equilibrium paths with $\varepsilon_0 > 0$.[18] Assume to the contrary that $\varepsilon_0 < 0$. In this case, ruling out explosive paths and given the continuity of ε_t at T, the final steady state must be characterized by $\varepsilon_T < 0$. The government's flow budget constraint can be written as $\dot{h}_t = rh_t + \pi_t m_t - \bar{g}$. By continuity of ε_t, (7) and (2), the path of real money demand and therefore of reserves is continuous at T, with $h_T = 0$. On the other hand π_t would have to be positive just before T by (11) and the fact that the inflation target is zero.

[18] The nominal interest rate must therefore be positive at all times, validating our assumption that the cash-in-advance constraint is binding.

At T, π_t would therefore have to jump from $\pi_{T^-} > 0$ to $\varepsilon_T < 0$, and therefore $\dot{h}_t < 0$ for $t \geq T$. This violates (14) and can therefore not be an equilibrium.

We now explain how to compute ε_0 and T simultaneously. The two variables are determined by two conditions, (i) $\varepsilon_T = \gamma\bar{g}/\alpha c_T^*$ and (ii) $h_T = 0$. Using (7), the first of these conditions implies

$$\tilde{f} \equiv \frac{\varepsilon_T}{\lambda(1 + \alpha r + \alpha\varepsilon_T)} - \frac{\bar{g}}{\alpha} \equiv 0 \, . \tag{A.3}$$

By the implicit function theorem

$$\frac{dT}{d\varepsilon_0} = -\frac{\frac{\partial \tilde{f}}{\partial \varepsilon_0}}{\frac{\partial \tilde{f}}{\partial T}} = -\frac{\frac{\partial \varepsilon_T}{\partial \varepsilon_0}\lambda(1 + \alpha r) - \varepsilon_T \frac{\partial \lambda}{\partial \varepsilon_0}(1 + \alpha r + \alpha\varepsilon_T)}{\frac{\partial \varepsilon_T}{\partial T}\lambda(1 + \alpha r) - \varepsilon_T \frac{\partial \lambda}{\partial T}(1 + \alpha r + \alpha\varepsilon_T)} < 0 \, , \tag{A.4}$$

because, as is easy to verify from (A.1) and (A.2),

$$\frac{\partial \lambda}{\partial T} < 0, \ \frac{\partial \lambda}{\partial \varepsilon_0} < 0, \ \frac{\partial \varepsilon_T}{\partial T} > 0, \ \frac{\partial \varepsilon_T}{\partial \varepsilon_0} > 0 \, .$$

There is therefore a strictly monotonic relationship between ε_0 and T. The second condition is $h_T = 0$. Using (12) and (A.4), h_T is expressible as a function of T alone as follows:

$$h_T = \left\{ h_0 + \Delta h_0(T) - \int_0^T [\frac{\gamma}{1-\gamma}(\varepsilon m)_t(T) + \bar{g}] e^{-rt} dt \right\} e^{rT} \, , \tag{A.5}$$

where $\Delta h_0(T) = [\bar{g}(1 + \alpha r + \alpha\varepsilon_T(T))]/[(1 + \alpha r + \alpha\varepsilon_0(T))\varepsilon_T(T)] - \alpha y^*/\gamma$. Ideally one would use (A.3) and (A.5) simultaneously to solve for the solution (ε_0^*, T^*), but this generates numerical problems when, as in our problem, ε_0 is extremely close to zero. We proceed sequentially instead, first solving (A.3) for $T(\varepsilon_0)$ with ε_0 given[19], and then solving

[19] Numerical integration is used to solve for λ using (A.2).

(A.5) for h_T given the same ε_0. We repeat this by varying ε_0 along a discretized interval $\varepsilon_0 \in (0, \overline{\varepsilon})$, and a solution (ε_0^*, T^*) is obtained when $h_{T^*} = 0$.

It remains to be shown that the computed solution is unique. Given a value for ε_0, the corresponding $T(\varepsilon_0)$ is unique by (A.4). However, the sign of the expression dh_T/dT is analytically ambiguous. Numerically we find that our solutions are locally unique by computing $dh_T/dT|_{T^*} < 0$. Figure 4 shows the behavior of h_T for T between slightly greater than 0 and just less than 8 quarters, which corresponds to $\varepsilon_0 \in [6e^{-3}, 6e^{-25}]$. It is suggestive of global uniqueness, and in our experience this is robust across a broader range of parameter values and policy experiments.

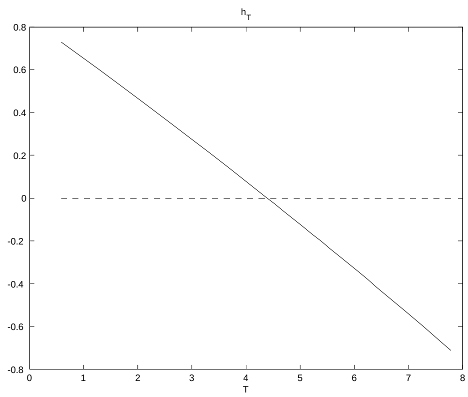

Figure 4 : h_T

Appendix B

We discuss the case of strict levels targeting, and show that this implies differences in initial reserve positions but an identical timing of regime collapse under all three monetary policies. The current account is given by

$$\dot{f}_t = rf_t + y^* - c_t^* \ . \tag{B.1}$$

We integrate this equation from 0 to T^-, where T^- is the instant before the regime collapse, and use the proportionality between c_t^* and m_t given by (8). Let m_0 be real balances before the announcement of higher spending, let m_1 be real balances in the instant after that announcement, and let m_{T^-} and m_2 be real balances in the instant just before and just after the regime's collapse, i.e. $m_t = m_2 \ \forall t \in [T, \infty)$. Then one can show that

$$e^{rT^-}(m_1 - m_0) = m_1 - m_{T^-} + r\int_0^{T^-} (m_1 - m_t)e^{r(T^- - t)}dt \ . \tag{B.2}$$

Furthermore,

$$\int_0^{T^-} m_t e^{-rt}dt = \frac{m_1}{r} - \frac{m_{T^-}}{r}e^{-rT^-} + \frac{1}{r}\int_0^{T^-} \dot{m}_t e^{-rt}dt \ . \tag{B.3}$$

Combining (B.2) and (B.3), and allowing for discontinuous jumps in real balances at T, we obtain

$$e^{rT^-}(m_1 - m_0) = -\int_0^{T^-} \dot{m}_t e^{r(T-t)}dt + (m_{T^-} - m_2) \ . \tag{B.4}$$

The key question for balance of payments crises is the extent to which these movements in real money balances are reflected in foreign exchange reserve movements. Clearly under exchange rate targeting h_t moves one-for-one with changes in m_t, and under domestic inflation targeting h_t does not move at all with m_t. Under CPI inflation targeting, constancy of P_t in (10) together with (9) implies that

$$m_t = \kappa M_t^{\frac{1}{\gamma}} \ , \tag{B.5}$$

where κ is a constant. The extent of reserve gains or losses is determined by the seigniorage terms $\dot{M}_t/E_t$ (for flow seigniorage) or dM_t/E_t (for seigniorage from discontinuous jumps in money demand). Applied to our problem, and using (B.5), we have the following terms:

$$\begin{aligned} \dot{h}_t^m &= \frac{\dot{M}}{E_t} = \mu_t m_t = \gamma \dot{m}_t \ , \\ dh_0^m &= h_1^m - h_0^m = \frac{M_1 - M_0}{E_0} = \gamma(m_1 - m_0) \ , \\ dh_{T^-}^m &= h_T^m - h_{T^-}^m = \frac{M_T - M_{T^-}}{E_{T^-}} = \gamma(m_2 - m_{T^-}) \ , \end{aligned} \tag{B.6}$$

where the superscript m refers to reserve changes due to seigniorage, as distinct from reserve changes due to government spending. Given this strict proportionality between money and reserve changes at all times we can rewrite (B.4) as

$$e^{rT}(h_1^m - h_0^m) = -\int_0^{T^-} \dot{h}_t^m e^{r(T-t)} dt + (h_{T^-}^m - h_2^m) \ . \tag{B.7}$$

This means that under all forms of exact levels targeting the interest compounded initial reserve gains are exactly equal to the subsequent reserve losses during the attack. Under domestic inflation targeting both terms are zero, under exchange rate targeting the second term on the right-hand side of (B.7) equals the left-hand side (with the integral zero), and under CPI inflation targeting the integral equals the left-hand side. Given that all remaining reserve losses are due to fiscal spending, which is equal across regimes, the complete depletion of reserves must happen at exactly the same time.

We have confirmed this in numerical simulations analogous to Figure 2, where except for the time of regime collapse the time profiles of all variables closely resemble those of the monetary accomodation case. Most notably, the pattern of Reserve Loss Ratios across different γ is identical.

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