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ABSTRACT

Central banks typically raise short-term interest rates to defend currency pegs. Higher interest rates, however, often lead to a credit crunch and an output contraction. We model this trade-off in an optimizing, first-generation model in which the crisis may be delayed but is ultimately inevitable. We show that higher interest rates may delay the crisis, but raising interest rates beyond a certain point may actually bring forward the crisis due to the large negative output effect. The optimal interest rate defense involves setting high interest rates (relative to the no defense case) both before and at the moment of the crisis. Furthermore, while the crisis could be delayed even further, it is not optimal to do so.

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1 Introduction

The last fifteen years have witnessed a succession of currency crises, ranging from the EMS crises in 1992 to similar episodes in Mexico (1994), Asia (1997), Russia (1998), Brazil (1999), and Argentina (2001). Given the economic dislocations that inevitably accompany a balance of payments (BOP) crisis, the design of appropriate policies to fight and prevent such occurrences is an issue of critical importance to policymakers and academics alike. As casual evidence makes abundantly clear, the standard first line of defense against mounting pressure on an exchange rate peg is to raise short-term interest rates. In fact, higher interest rates to defend a peg (or, more generally, strengthen the domestic currency) are a standard component of IMF programs, as implemented in Russia, Brazil, and most Asian countries (Fischer, 1998). The desirability of such policies, however, has become a matter of intense debate in the policy arena.[1]

The standard rationale among policymakers for raising short-term interest rates is to make domestic-currency denominated assets more attractive (hereafter referred to as the "money demand effect"). This should slow down (or, hopefully, stop altogether) the loss of reserves under a pegged exchange rate. On the cost side, both proponents and detractors essentially agree that a high interest rate policy entails mainly three type of costs: (i) a fiscal cost in the form of a higher operational deficit, which results from higher interest rates on public debt; (ii) an output cost, as high interest rates lead to a credit crunch and an output contraction; and (iii) a further deterioration of an already weak banking system (when applicable). The policy debate centers on the implicit assessment of the benefits versus the costs of higher interest rates, with proponents emphasizing the short-run benefits of currency stability and detractors focusing on the magnitude of the costs.

[1]IMF critics like Jeff Sachs and Joe Stiglitz, for instance, have vehemently argued against high interest rate policies in numerous pieces in the financial press.

For all the practical importance of this issue, there was until recently little, if any, academic work focusing explicitly on this debate. The seminal work on currency crises by Krugman (1979) and Flood and Garber (1984) – and most of the ensuing literature – gives no role to the monetary authority in fighting a potential crisis, as it implicitly assumes that policymakers sit passively as they watch international reserves dwindle down until the final speculative attack wipes them out completely. Only recently has an incipient theoretical literature begun to explicitly address this topic.[2] In particular, in Lahiri and Végh (2003), we analyze the effectiveness and optimality of raising short-term interest rates to defend a peg by focusing on the trade-off between the money demand effect and the fiscal cost. We show that higher interest rates may indeed delay a BOP crisis – which in practice may buy precious time for policymakers to address the fundamental imbalances. Raising interest rates beyond a certain point, however, may actually bring the crisis forward as the fiscal effect begins to dominate the money demand effect. There is thus some increase in interest rates that will maximize the delay. We also show, however, that it is not optimal to delay the crisis as much as possible. Our analysis thus validates some of the critics' concerns about the perils of higher interest rates, while still offering a formal rationale for the monetary authority to play an active role in defending a currency peg.[3] However, our analysis in that paper abstracts completely from output effects of higher interest rates.

[2] See Drazen (2003), Flood and Jeanne (2005), and Lahiri and Végh (2003). Empirically, the evidence on the effectiveness of higher interest rates in defending/strengthening the domestic currency is mixed (see, for example, Dekle, Hsiao, and Wang (2001) and Kraay (2001)).

[3] Flood and Jeanne (2005) also focus on the fiscal costs of higher interest rates. Drazen (2003), on the other hand, looks at the signalling effects of higher interest rates. Our analysis is also related to Burnside, Eichenbaum, and Rebelo (2001a), where the government can delay the time of the crisis by further borrowing (which implies higher interest rates in the future) but, unlike in our model, there are no benefits from doing so.

In this paper, we focus our attention on the output costs of higher interest rates, which is arguably the most important channel. As Figure 1 illustrates for four emerging economies that have actively defended their currencies by raising short-term interest rates, higher interest rates are typically associated with an output contraction (with vertical lines in the figures denoting periods of active interest rate defense).[4] Figure 2 illustrates, in turn, the link between credit contractions and higher interest rates. The figure suggests that higher interest rates depress the economy through a credit channel.

We address the trade-off between the money demand effect and the output effect in the context of an otherwise standard, optimizing, small open economy that is prone to Krugman-type crises.[5] To this effect, we incorporate a credit channel by assuming that firms are dependent on bank credit for their productive activities, while banks need deposits to make loans. Following Calvo and Végh (1995), we model interest rate policy as the monetary authority's ability to set the interest rate on an interest-bearing liability (a non-traded domestic bond). We assume that this domestic bond is held only by domestic commercial banks. Raising the interest rate on this domestic bond increases both the lending rate to firms as well as the deposit rate paid to depositors. The latter effect increases money demand (defined as the demand for demand deposits) and may postpone the time of the attack. The higher lending rate, however, reduces bank credit to firms and, hence, extracts an output cost by reducing employment and output.[6]

[4] The data for Figures 1 and 2 comes from the IMF's *International Financial Statistics*. For detailed evidence on the contractionary effects of currency crises, see Calvo and Reinhart (1999) and Gupta, Mishra, and Sahay (2002).

[5] By a Krugman-type crisis, we mean an environment in which the central bank fixes the exchange rate but follows an expansionary domestic credit policy.

[6] We should note that the mechanism through which an interest rate defense works in our set-up is different from another, more common, channel. Under our mechanism, the interest rate defense works by raising the demand for the domestic money base. This reduces the size of the attack at the time of the crisis and thereby

Within this model, our main question is: given the Krugman distortion (i.e., an unsustainable fixed exchange rate), can policymakers delay the crisis by raising interest rates? And, if so, what is the optimal interest rate defense? To answer these questions, we first distinguish between two types of interest rate defense (both of which are announced as of time zero): (i) a *contemporaneous* interest rate defense of the peg whereby the monetary authority announces that it will raise the domestic interest rate only when the market interest rate rises; and (ii) a *preemptive* interest rate defense of the peg whereby the monetary authority raises the domestic interest rate before the crisis actually occurs.

We show that both the preemptive and the contemporaneous interest rate defense succeed in delaying the crisis (at the cost of a fall in output) but only up to a certain point. Beyond some critical level, raising interest rates further may actually bring the crisis forward. We then show that – relative to the no-defense case – it is always optimal to announce high interest rates both before and at the time of the crisis. Hence, it is not optimal for the central bank to remain passive as its reserves dwindle, as implicitly assumed by first-generation models of BOP crises. Furthermore, at an optimum, higher interest rates at the time of the crisis would succeed in further delaying the crisis but such a policy would obviously not be optimal.

In sum, our model provides a simple framework to think about the trade-offs involved in an active interest rate defense of a peg. It suggests that there is indeed a role for an active

postpones the attack. In the alternative view, interest rate defenses work by raising the cost of speculation to the point where the additional cost of speculation offsets the expected devaluation of the currency. In our perfect foresight environment, there is no discrete devaluation and thus this channel does not apply. In any event, this alternative mechanism has been critiqued on the grounds that, to be effective in deterring speculators, interest rates must be raised to unreasonable levels. Thus, Drazen (1993) argues that "... even if foreign currency assets bore no interest, an expected overnight devaluation of 0.5 percent would require an annual interest rate over 500 percent $((1.005)^{365}$-1) x 100 = 517) to make speculation unprofitable."

interest rate defense, thus calling into question the policy relevance of models that assume away this policy option. The presence of output costs, however, imposes clear limits to the use of higher interest rates, which are captured in the model by the fact that the time of the crisis is a non-monotonic function (inverted U) of the level of interest rates. While, by necessity, the model abstracts from many other relevant channels in practice, we believe that it captures an essential trade-off between the costs and benefits of delaying a crisis.

Before proceeding further, some remarks about our modelling strategy are in order. In any open economy set-up, allowing for an independent interest rate policy channel to co-exist with an independent exchange rate policy involves deviating from the assumption of perfect substitutability between domestic and foreign assets. In our model this is accomplished by introducing a non-traded domestic bond that is held only by domestic banks, which in turn cannot hold foreign bonds. Within this structure, if we allowed any subset of agents to simultaneously hold both domestic and foreign bonds, the no-arbitrage condition would immediately equalize domestic and foreign returns and hence eliminate the central bank's ability to independently set the interest rate on domestic bonds. While this assumption seems stark, it is not as restrictive as might seem at first glance. There are alternative ways of breaking the no-arbitrage relationship without changing the key underlying mechanism through which an interest rate defense works in the model. Thus, as in Calvo and Végh (1995), we could allow households to hold these domestic bonds along with the foreign bonds but assume that these domestic bonds provide liquidity services, i.e., one can write checks on these holdings. Alternatively, one could allow banks to also hold foreign bonds but introduce a costly banking technology as in Edwards and Végh (1997) wherein banks face a cost of managing domestic assets. Under either of these scenarios, this paper's results would carry through.

The paper proceeds as follows. Section 2 develops the model, while Section 3 works out the mechanics of a BOP crisis under a passive interest rate policy. Section 4 analyzes the effects of an active interest rate defense on output and the timing of the crisis. Section 5 derives the optimal interest rate defense of the peg. Section 6 concludes.

2 The model

Consider a small open economy that is perfectly integrated with the rest of the world in goods markets. The economy is inhabited by an infinitely-lived representative household that receives utility from consuming a perishable good and disutility from supplying labor. The world price of the good in terms of foreign currency is fixed and normalized to unity. Free goods mobility across borders implies that the law of one price holds. The consumer can also trade freely in perfectly competitive world capital markets by buying and selling an international bond. These international bonds are denominated in terms of the good and pay a constant r units of the good as interest at every point in time.

2.1 Households

The household maximizes lifetime welfare, which is given by

$$W \equiv \int_0^\infty \frac{1}{1-1/\sigma}\left[(c_t - \zeta x_t^\nu)^{1-1/\sigma} - 1\right] e^{-\beta t} dt, \quad \sigma > 0, \quad \zeta > 0, \quad \nu > 1, \tag{1}$$

where c denotes consumption, x is labor supply, σ is the intertemporal elasticity of substitution, $\nu - 1$ is the inverse of the elasticity of labor supply with respect to the real wage (as will become evident below), and $\beta(> 0)$ is the exogenous and constant rate of time preference. These preferences are well-known from the work of Greenwood, Hercowitz and Huffman (1988) and have been widely used in the real business cycle literature, as they provide a better description of consumption and the trade balance for small open economies than alternative specifications (see, for instance, Correia, Neves, and Rebelo (1995)). In our case, we adopt these preferences for analytical tractability since it will enable us to derive our key results analytically.[7]

Households use interest-bearing demand deposits to reduce transactions costs. For simplicity, we will assume that transactions costs depend only on real demand deposits (but not on consumption). Specifically, the transactions costs technology takes the standard form

$$s_t = \psi(h_t), \tag{2}$$

where s denotes the non-negative transactions costs incurred by the consumer and h denotes real interest-bearing demand deposits. Additional real demand deposits reduce transactions costs, but at a decreasing rate. Formally:

$$\psi(h) \geq 0, \quad \psi'(h) \leq 0, \quad \psi''(h) > 0, \quad \psi'(h^*) = \psi(h^*) = 0.$$

The assumption that $\psi'(h^*) = 0$ for some finite value of h $(= h^*)$ ensures that the consumer can be satiated with real money balances (i.e., the Friedman rule can be implemented). At that point, transactions costs are assumed to be zero.

In addition to demand deposits, households can hold an internationally-traded bond (b). Real financial wealth at time t is thus given by $a_t = b_t + h_t$. We denote the deposit rate by i^d. No arbitrage on the internationally-traded bond implies that the nominal interest rate is given by $i = r + \varepsilon$, where ε denotes the rate of devaluation. Hence, the opportunity cost of holding demand deposits is $I^d \equiv i - i^d$ (the deposit spread).[8] The flow budget constraint facing the representative household is thus given by

$$\dot{a}_t = ra_t + w_t x_t + \tau_t - c_t - s_t - I_t^d h_t + \Omega_t^f + \Omega_t^b, \tag{3}$$

[7] The key analytical simplification introduced by GHH preferences is that there is no wealth effect on labor supply.

[8] It will be assumed throughout that $I^d \geq 0$.

where w denotes the real wage, τ are lump sum transfers received from the government, while Ω^f and Ω^b denote dividends received from firms and banks, respectively. Integrating (3) and imposing the standard transversality condition yields the household's lifetime budget constraint:

$$a_0 + \int_0^\infty (w_t x_t + \tau_t + \Omega_t^f + \Omega_t^b) e^{-rt} dt = \int_0^\infty (c_t + I_t^d h_t + s_t) e^{-rt} dt. \tag{4}$$

The household chooses paths for $\{c_t, x_t, h_t\}$ to maximize lifetime utility (1) subject to (2) and (4), taking as given a_0, r, and the paths for I_t^d, w_t, Ω_t^f, and Ω_t^b. The first-order conditions for this problem are given by (assuming, as usual, that $\beta = r$):

$$(c_t - \zeta x_t^\nu)^{-1/\sigma} = \lambda, \tag{5}$$

$$\nu \zeta x_t^{\nu - 1} = w_t, \tag{6}$$

$$-\psi'(h_t) = I_t^d, \tag{7}$$

where λ is the (time-invariant) Lagrange multiplier associated with constraint (4). Equation (5) says that the marginal utility of consumption is constant along a perfect foresight equilibrium path. Equation (6) shows that labor supply depends positively on the real wage, w. Finally, equation (7) implicitly defines the demand for real demand deposits as a decreasing function of their opportunity cost, I^d:

$$h_t = \tilde{h}(I_t^d), \tag{8}$$

$$\tilde{h}'(I_t^d) = -\frac{1}{\psi''(h_t)} < 0. \tag{9}$$

2.2 Firms

The representative firm's production function is assumed to be linear in labor:[9]

$$y_t = x_t. \tag{10}$$

Firms are assumed to face a "credit-in-advance" constraint, in the sense that they need to borrow from banks to pay the wage bill.[10] Formally:

$$n_t = \phi w_t x_t, \quad \phi > 0, \tag{11}$$

where n denotes bank loans.[11] The assumption that firms must use bank credit to pay the wage bill is needed to generate a demand for bank loans.

Firms may also hold foreign bonds, b^f. Thus, the real financial wealth of the representative firm at time t is given by $a_t^f = b_t^f - n_t$. Using i^ℓ to denote the lending rate charged by banks and letting $I^\ell \equiv i^\ell - i$ denote the lending spread, we can write the flow constraint faced by the firm as

$$\dot{a}_t^f = ra_t^f + y_t - w_t x_t(1 + \phi I_t^\ell) - \Omega_t^f. \tag{12}$$

It is easy to see from equation (12) that $w_t x_t \phi I_t^\ell (= I_t^\ell n_t)$ is the additional financial cost incurred by firms due to the fact that they need to borrow from banks to pay the wage bill. Integrating forward equation (12), imposing the standard transversality condition, and using equation (10) yields

$$\int_0^\infty \Omega_t^f e^{-rt} dt = a_0^f + \int_0^\infty \left[x_t - w_t x_t(1 + \phi I_t^\ell)\right] e^{-rt} dt. \tag{13}$$

[9] We adopt a linear production technology purely for analytical simplicity and without loss of generality.

[10] Alternatively, we could assume that bank credit is an input in the production function, in which case the derived demand for credit would be interest-rate elastic. This would considerably complicate the model without adding any additional insights.

[11] Note that the credit-in-advance constraint (equation (11)) will hold as an equality only along paths where the lending spread I^ℓ is strictly positive. We will assume (with no loss of generality) that if $I^\ell = 0$, this constraint holds with equality as well.

The firm chooses a path of x to maximize the present discounted value of dividends, which is given by the right hand side of equation (13), taking as given a_0^f, r, and the paths for w_t and I_t^ℓ. The first-order condition for this problem is given by

$$1 = w_t(1 + \phi I_t^\ell). \tag{14}$$

Intuitively, at an optimum, the firm equates the marginal productivity of labor (unity) to the marginal cost of an additional unit of labor, given by the real wage, w_t, plus the associated financial cost, $w_t \phi I_t^\ell$.

2.3 Banks

The economy is assumed to have a perfectly competitive banking sector. The representative bank accepts deposits from consumers and lends to both firms (n) and the government (z) in the form of domestic government bonds.[12] The bank charges an interest rate of i^ℓ to firms and earns i^g on government bonds. It also holds required cash reserves, m (high powered money). The bank pays depositors an interest rate of i^d. Assuming, for simplicity, that banks' net worth is zero, the balance sheet identity implies that $m_t + n_t + z_t = h_t$. As noted in the introduction, the assumption that domestic banks do not hold foreign assets is key to the ability of the central bank to independently set the domestic interest rate.[13]

[12] Commercial bank lending to governments is particular common in developing countries (see, for instance, Calvo and Végh (1995) and the references therein). Government debt is held not only as compulsory (and remunerated) reserve requirements but also voluntarily due to the lack of profitable investment opportunities in crisis-prone countries.

[13] Similar results would go through if we allowed banks to hold foreign bonds as long as they faced a cost of managing domestic assets (along the lines of Edwards and Végh (1997), Burnside, Eichenbaum, and Rebelo (2001b), or Agenor and Aizenman (1999)). We chose the specification with no foreign borrowing because it is analytically simpler.

The flow constraint faced by the bank is then given by

$$\Omega_t^b = (i_t^\ell - \varepsilon_t)n_t + (i_t^g - \varepsilon_t)z_t - (i_t^d - \varepsilon_t)h_t - \varepsilon_t m_t. \tag{15}$$

It is assumed that the central bank imposes a reserve-requirement ratio $\delta > 0$. Since required reserves do not earn interest, at an optimum the bank will not hold any excess reserves. Hence, we must have

$$m_t = \delta h_t. \tag{16}$$

Equation (16) implies that the representative commercial bank's balance sheet identity can be written as

$$(1 - \delta)h_t = n_t + z_t. \tag{17}$$

The representative bank maximizes profits given by equation (15) by choosing sequences of n_t, z_t, h_t and m_t subject to equations (16) and (17), taking as given the paths of i_t^ℓ, i_t^g, i_t^d, and ε_t. The first-order conditions for the banks' optimization problem are

$$(1 - \delta)\, i_t^\ell = i_t^d, \tag{18}$$

$$(1 - \delta)\, i_t^g = i_t^d. \tag{19}$$

Since the banks do not control any of the interest rates, conditions (18) and (19) should be interpreted as competitive equilibrium conditions. In this light, conditions (18) and (19) say that, in equilibrium, the deposit rate(i^d) – which captures the marginal cost of deposits for the banks – will be equal to the marginal revenue from an extra unit of deposits. Since the banks can only lend a fraction $1 - \delta$ of deposits, the marginal revenue is either $(1 - \delta)\, i_t^\ell$ or $(1 - \delta)\, i_t^g$. Clearly, from (18) and (19), it follows that

$$i^\ell = i^g. \tag{20}$$

Intuitively, loans and government bonds are perfect substitutes in the bank's asset portfolio. Since the bank can get i^g by lending to the government, it must receive at least as much from firms in order to extend loans to them. Hence, in equilibrium, any change in the domestic interest rate i^g will automatically translate into a rise in the lending rate, i^ℓ. Further, from (19), it follows that a rise in i^g will also lead to a higher deposit rate for consumers and, hence, an increase in demand deposits.

2.4 Government

The government comprises the monetary and the fiscal authority. For simplicity, it will be assumed that the monetary authority issues both high powered money, m, and domestic bonds, z. The monetary authority also pays interest on these bonds, i^g, holds interest-bearing foreign exchange reserves, f, and sets the reserve requirement ratio, δ. The fiscal authority makes lump-sum transfers, τ, to the public. We assume that these fiscal transfers are fixed and invariant over time. Hence, $\tau_t = \bar{\tau}$ for all t. The consolidated government's flow budget constraint is thus given by

$$\dot{f}_t = rf_t + \dot{m}_t + \dot{z}_t + \varepsilon_t m_t + (\varepsilon_t - i_t^g)z_t - \bar{\tau}. \tag{21}$$

Note that the inflation tax is given by $\varepsilon_t m_t$ in the case of high powered money (which is only held by banks in this economy) and $(\varepsilon_t - i_t^g)z_t$ in the case of domestic bonds.

Let d denote the stock of real domestic credit. Since the monetary authority issues interest-bearing debt, its *net* domestic credit, d^n, is given by $d - z$. We assume that the government's domestic credit policy consists of setting a rate of growth for net domestic credit:

$$\frac{\dot{D}_t^n}{D_t^n} = \mu_t, \tag{22}$$

where D^n denotes net nominal domestic credit. Let E denote the nominal exchange rate, that is, the price of foreign currency in terms of domestic currency. From the central bank's balance sheet, $\dot{f}_t = \dot{m}_t - \dot{d}_t^n$, where $d^n = D^n/E$. Further, note that $\dot{d}_t^n = (\mu_t - \varepsilon_t)d_t^n$. Using these two facts, equation (21) can be rewritten as:

$$\bar{\tau} = rf_t + (\mu_t - \varepsilon_t)d_t^n + \varepsilon_t m_t + (\varepsilon_t - i_t^g)z_t + \dot{z}_t. \tag{23}$$

Finally, integrating forward (21) and imposing the no-Ponzi games condition yields:

$$\frac{\bar{\tau}}{r} = f_0 + \int_0^\infty \left[\dot{m}_t + \dot{z}_t + \varepsilon_t m_t + (\varepsilon_t - i_t^g)z_t\right] e^{-rt}dt + e^{-rT} \triangle m_T, \tag{24}$$

where the last term on the RHS allows for the possibility of a discrete change in real liabilities at some time $t = T$.[14] We also assume that the initial stock of net domestic credit and initial real money demand are such that $f_0 > 0$.

2.5 Equilibrium relations

The firm's optimality condition (equation (14)) implies that, in equilibrium, the real wage is given by

$$w_t = \frac{1}{1 + \phi I_t^\ell}. \tag{25}$$

Intuitively, a higher I^ℓ makes bank credit more expensive for firms, which increases production costs and, hence, reduces firms' demand for labor, thus lowering the real wage. We can combine equations (6) and (25) to get

$$\nu\zeta x_t^{\nu-1} = \frac{1}{1 + \phi I_t^\ell}, \tag{26}$$

which shows that, at an optimum, a higher lending spread must reduce employment, x. Equation (26) implies that equilibrium employment is given by

$$x_t = \left(\frac{1}{\nu\zeta}\right)^{\frac{1}{\nu-1}} \left(\frac{1}{1 + \phi I_t^\ell}\right)^{\frac{1}{\nu-1}}. \tag{27}$$

[14] Throughout the paper, we denote a discrete change in, say, variable x as $\Delta x_T \equiv x_T - x_{T^-}$. Note that since the central bank controls *net* domestic credit, any discrete change in z is exactly offset by a change in gross domestic credit. Hence, only discrete changes in m enter the last term on the RHS of equation (24).

The equilibrium amount of loans in this economy is given by (as follows from (25) and (26) and the fact that $n = \phi w x$)

$$n_t = \phi \left(\frac{1}{\nu\zeta} \right)^{\frac{1}{\nu-1}} \left(\frac{1}{1+\phi I_t^{\ell}} \right)^{\frac{\nu}{\nu-1}}. \tag{28}$$

The crucial feature to note from equations (26) and (28) is that a rise in the lending spread induces a fall in output and in bank credit. Hence, a recession in this economy is characterized by a rise in the lending spread which, in turn, is linked one-for-one with the domestic interest rate, i^g. Since equation (20) implies that $I^g = I^l$ for all t, one can use equation (28) to express the demand for loans as

$$n_t = \tilde{n}(I_t^g). \tag{29}$$

Lastly, by combining the flow constraints for the consumer, the firm, the bank, and the government (equations (3), (12), (15) and (21)) and using equations (10), (11), and (16), we get the economy's flow resource constraint:

$$\dot{k}_t = r k_t + x_t - c_t - \psi(h_t), \tag{30}$$

where $k = b + b^f + f$. Note that the RHS of equation (30) is simply the current account. Integrating forward subject to the No-Ponzi game condition yields

$$k_0 + \int_0^{\infty} [x_t - c_t - \psi(h_t)] e^{-rt} dt = 0. \tag{31}$$

2.6 Exchange rate and interest rate policy

As in standard first-generation currency crisis models, we assume that at $t = 0$ the exchange rate is fixed at the level $\bar{E}$. In addition, it is assumed that there is a critical lower bound for international reserves (say, $f_t = 0$). It is known by all agents at $t = 0$ that, if and when that critical level of reserves is reached, the central bank will cease to intervene in the foreign exchange market and will allow the exchange rate to float freely. As a matter of terminology, we will refer to the switch from the fixed exchange rate to the floating rate as a "crisis".

The key feature of our model is that, in addition to fixing the exchange rate, the central bank can also set the path for the interest rate on the domestic bond, i^g (referred to as the "domestic" interest rate). Importantly, setting i^g implies that the central bank allows the composition of its liabilities (non-interest bearing monetary base and interest bearing domestic bonds) to be market determined. Alternatively, of course, the central bank could set the composition of its liabilities and let i^g be market determined. In what follows below, we shall assume that i^g is the central bank's policy instrument while the composition of its liabilities is determined endogenously. Moreover, we shall restrict attention to piecewise flat paths for i^g.

As noted above, the ability of the central bank to independently set a path for the domestic interest rate stems from our assumption that domestic bonds are held only by domestic banks which, in turn, cannot hold any foreign bonds. Hence, differences in returns on these two assets cannot be arbitraged away through asset trade. However, the non-negativity restriction on the deposit spread, $I^d > 0$, still imposes the restriction that $i^g < \frac{i}{1-\delta}$. Hence, the central bank cannot choose any arbitrarily-high level of the domestic interest rate. It bears repeating, however, that there are alternative ways of introducing imperfect asset substitutability which preserve the monetary authority's ability to influence domestic interest rates. Thus, introducing a liquidity service from domestic bonds (as in Calvo and Végh (1995) and Lahiri and Végh (2003)) or a costly banking technology for managing domestic assets (as in Edwards and Végh (1997)) would also introduce an endogenous wedge between the foreign and domestic interest rates. The effectiveness of interest rate policy then resides in the ability of the central bank to influence the wedge by an appropriate choice of policy. Of course, the interpretation of the wedge as well as the precise extent to which the policymaker can manipulate the domestic interest rate would depend on how imperfect asset substitutability is introduced. In the case of liquid bonds, the wedge would be the liquidity services offered by the domestic bonds while in the case of a costly banking technology the wedge would be interpreted as the marginal cost of managing domestic assets.

Even in the context of the model presented here, it is possible to derive an interest parity condition between the domestic interest rate (i^g) and the market interest rate (i). Specifically, use (7) and (19) to obtain

$$i_t^g = \frac{i_t}{1-\delta} - \frac{[-\psi'(h_t)]}{1-\delta}. \tag{32}$$

This condition says that, in equilibrium, the domestic interest rate must equal the market interest rate (adjusted by reserve requirements) *minus* a liquidity premium (given by $\frac{-\psi'(h_t)}{1-\delta} > 0$). As expected, the liquidity premium is a decreasing function of the stock of demand deposits (recall that $\psi'' > 0$). In other words, what enables the government to set a domestic interest rate that differs from the (adjusted) market interest rate is that setting the domestic interest rate effectively amounts to setting the interest rate on demand deposits (i.e., paying interest on money). Since demand deposits provide liquidity, the return required by households to hold them will be below the market interest rate. Hence, a higher domestic rate will be associated with a lower liquidity premium (i.e., a higher level of demand deposits). If demand deposits offered no liquidity services (i.e., $\psi' = 0$), then the domestic interest rate could not differ from the adjusted market interest rate. Importantly, this would be true despite the non-tradability of the domestic asset.

As will become clear below, a higher rate on domestic bonds paid by the central bank will have three effects. First, since government bonds and bank credit to firms are perfect substitutes in the banks' portfolio, a higher interest rate on government bonds will lead to a *pari passu* increase in the lending rate. This will curtail bank credit and, all else equal, provoke an output contraction. This effect will be referred to as the *output effect* of interest rate policy.[15] Second, a higher interest rate on domestic bonds will increase the debt servicing burden of the consolidated government which we shall refer to as the *fiscal effect*.[16] Third, the higher interest rate on government bonds will induce banks to also pay a higher rate on bank deposits (recall (19)). This higher rate on deposits reduces the opportunity cost of holding bank deposits and thus increases demand for bank deposits. We will refer to this as the *money demand effect*.

3 Balance of payments crises

This section first characterizes the perfect foresight equilibrium path for this economy and then studies the case in which there is no attempt on the part of the monetary authority to engage in an active interest rate defense. We refer to this case as "passive interest rate policy". It provides the natural benchmark for analyzing the effects of active interest rate policy in later sections.

3.1 Solving the model

In what follows, we shall focus on stationary environments in which the policy-controlled interest rate, i^g, is piecewise constant before and after T (at levels given by i_0^g and i_T^g,

[15] As discussed below, it is important to note that the output effect will also be associated with an indirect fiscal effect as commercial banks substitute out of bank lending and into government bonds, which increases the stock of government debt and hence debt service.

[16] It should be noted that we could abstract from the fiscal effect (by assuming that lump-sum government transfers are endogenous) and that our main results regarding the government's ability to delay a crisis and optimality of an active interest rate defense would still go through (as we show in a previous version of this paper). The fiscal effect is needed to obtain the non-monotonicities derived below (for which *both* the output and the fiscal effects must be present).

respectively) but may jump at that date. As is well known from Krugman (1979) and Flood and Garber (1984), the combination of a fixed exchange rate and an initial fiscal deficit makes a BOP crisis inevitable in this economy. To see this, note that a fixed exchange rate implies that the nominal interest rate is constant and given by $i_t = r$. From (18) and (20), it follows that i^ℓ and i^d will also be constant. Hence, $I^d(= i - i^d)$ will be constant and, in light of (7), so will demand deposits, h. Further, since I^ℓ is constant, by (25), (26), and (28), so will w_t, x_t, and n_t. From (17), it then follows that z_t will be constant. Given (16) and the constancy of h_t, m_t will also be constant. Finally, since x_t is constant over time, first-order condition (5) implies that c_t will be constant as well.

We now turn to the path of international reserves. Since m_t and h_t are constant over time, equation (21) implies that under a fixed exchange rate ($\varepsilon = 0$):

$$\dot{f}_t = rf_t - i_0^g z_t - \bar{\tau} < 0. \tag{33}$$

The assumption (which will be maintained throughout the paper) that $\bar{\tau} > rf_0$ is a sufficient condition for $\dot{f}_t < 0$. In other words, international reserves at the central bank will be falling over time. Furthermore – and as equation (33) makes clear – international reserves will be falling at an increasing rate. Since the lower bound for international reserves will be reached in finite time, the fixed exchange rate regime is unsustainable. The central bank will thus be forced to abandon the peg at some point in time T and let the exchange rate float. Fiscal spending remains unchanged at $\bar{\tau}$.

In order to derive the perfect foresight path for $t \geq T$, notice that since reserves fall to zero at $t = T$, $\dot{f}_t = f_t = 0$ for $t \geq T$, which enables us to rewrite equation (21) as

$$\bar{\tau} = \dot{m}_t + \dot{z}_t + \varepsilon_t m_t + (\varepsilon_t - i_t^g) z_t, \qquad t \geq T. \tag{34}$$

Taking into account (16), (17), and (19), this last equation becomes

$$\bar{\tau} = \dot{h}_t + \left(\varepsilon_t - i_t^d\right) h_t + \left(i_T^g - \varepsilon_t\right) n_t - \dot{n}_t, \qquad t \geq T. \tag{35}$$

Intuitively, notice that, for a given h – and as follows from the banks' balance sheet (17) – n and z move in opposite direction. Hence, a flow expansion of loans to firms ($\dot{n} > 0$) decreases revenues as it implies a reduction in the flow expansion of government bonds. Similarly, for given h, a higher n implies a smaller stock of bonds which reduces the real debt service.

Time-differentiating equations (7) and (28), using (8) and (29), and substituting the results into (35) yields an equilibrium differential equation in ε for $t \geq T$:

$$\dot{\varepsilon}_t = \Gamma\left[[\varepsilon_t - (1-\delta)i^g_T]\tilde{h}(I^d_t) + (i^g_T - \varepsilon_t)\,\tilde{n}(I^g_t) - \bar{\tau}\right], \tag{36}$$

where $\Gamma \equiv \left(-\tilde{n}' + \frac{1}{\psi''}\right)^{-1} > 0$. (Recall that $i = r + \varepsilon$, $I^d = r + \varepsilon - (1-\delta)i^g$, and $I^g = i^g - r - \varepsilon$.) In deriving the above, we have used the fact that under stationary policies $\dot{i}^g_t = 0$.

It is easy to check that, in a local neighborhood of the steady state, equation (36) is an unstable differential equation if and only if $\left(1 - \frac{I^d - r}{I^d}\eta_h\right) h - \left(1 - \frac{I^g + r}{I^g}\eta_n\right) n > 0$, where $\eta_h \equiv -\tilde{h}' I^d / h$ is the opportunity-cost elasticity of demand deposits, and $\eta_n \equiv -\tilde{n}' I^g / n$ is the interest elasticity of loans by firms (in general equilibrium).[17]

To understand this stability condition, note that in the steady state equation (35) reduces to

$$\bar{\tau} = \left(I^d - r\right) h + \left(I^g + r\right) n. \tag{37}$$

The expression $\left(1 - \frac{I^d - r}{I^d}\eta_h\right) h - \left(1 - \frac{I^g + r}{I^g}\eta_n\right) n$ is the effect of a change in ε on *net* government revenues. If both elasticities are less than unity, then a rise in ε increases inflation tax revenues from deposits (first term) and, for given h, increases the real debt service (second term) since an increase in ε reduces I^g. If this overall expression is positive, then equation (36) is unstable around the steady state. Hence, to ensure a unique convergent

[17] To simplify the derivation of some results below, we will assume that η_h is a strictly increasing function of the opportunity cost of holding deposits I^d. This property is satisfied by, among others, Cagan money demands, which provide the best fit for developing countries (see Easterly, Mauro, Schmidt-Hebbel (1995)).

perfect foresight equilibrium path, we shall restrict attention to parameter ranges for which $\left(1-\frac{I^d-r}{I^d}\eta_h\right)h-\left(1-\frac{I^g+r}{I^g}\eta_n\right)n>0$.

It follows then that for $t \geq T$ – and along any perfect foresight equilibrium path with constant $\bar{\tau}$ and $i^g-\varepsilon_t=\varepsilon_T$. A constant ε and i^g imply that i, I^d and I^g must all be constant over time. As above, this implies, by (5), (16), (17), (25), (26), and (28), that c, x, h, n, m, and z all remain constant as well. Lastly, the constancy of h implies that money demand is constant over time. Since $d^n=\delta h$ for all $t \geq T$, this implies that $\dot{d}_t^n=0$ and $\mu_t=\varepsilon_T$ for all $t \geq T$.

Before proceeding further, it is useful to note that the term $\left(1-\frac{I^d-r}{I^d}\eta_h\right)h$ reflects the well-known possibility of a Laffer curve relationship between revenues from money printing and the opportunity cost of holding money. As is standard, and to ensure that the economy is always operating on the "correct" side of the Laffer curve, we will assume throughout that $\left(1-\frac{I^d-r}{I^d}\eta_h\right)h>0$.

In order to tie down the equilibrium post-collapse values of all the endogenous variables, we need to determine the values of I_T^d and ε_T as functions of the post-collapse policy variables i_T^g and $\bar{\tau}$. We can totally differentiate (37) to implicitly solve for $I_T^d=\tilde{I}^d(I_T^g;\bar{\tau})$, where

$$\frac{\partial \tilde{I}^d}{\partial I_T^g}=-\frac{\left(1-\frac{I_T^g+r}{I_T^g}\eta_n\right)n_T}{\left(1-\frac{I_T^d-r}{I_T^d}\eta_h\right)h_T}. \tag{38}$$

The sign of this expression is ambiguous. It can be easily checked that $1 \gtreqless \frac{I_T^g+r}{I_T^g}\eta_n$ as $1+\phi I_T^g \lesseqgtr \nu(1-\phi r)$. Hence, if $1<\nu(1-\phi r)$, which will be our maintained assumption, then $\frac{\partial \tilde{I}^d}{\partial I_T^g}<0$ for low values of I_T^g but $\frac{\partial \tilde{I}^d}{\partial I_T^g}>0$ for all $I_T^g>[\nu(1-\phi r)-1/\phi]\equiv \hat{I}_T^g$.[18]

Substituting $I_T^d=\tilde{I}^d(I_T^g;\bar{\tau})$ into the bank's first-order condition (19), we can also solve for the stationary depreciation rate ε_T as an implicit function of I_T^g, for a given $\bar{\tau}$, i.e.,

[18] It is easy to establish numerically – using Cagan money demand functions – the existence of the case in which $I_T^g>\hat{I}_T^g$.

$\varepsilon_T = \tilde{\varepsilon}(I_T^g; \bar{\tau})$ where

$$\frac{\partial \tilde{\varepsilon}}{\partial I_T^g} = \frac{\left(1 - \frac{I_T^d - r}{I_T^d}\eta_h\right)(1-\delta)h_T - \left(1 - \frac{I_T^g + r}{I_T^g}\eta_n\right)n_T}{\left(1 - \frac{I_T^d - r}{I_T^d}\eta_h\right)\delta h_T}. \tag{39}$$

The sign of this expression is, in general, ambiguous.

Lastly, we can substitute $\tilde{\varepsilon}(I_T^g; \bar{\tau})$ into $I_T^g = i_T^g - r - \varepsilon_T$ to implicitly solve for $I_T^g = \tilde{I}^g(i_T^g; \bar{\tau})$ where

$$\frac{\partial \tilde{I}^g}{\partial i_T^g} = \frac{\left(1 - \frac{I_T^d - r}{I_T^d}\eta_h\right)\delta h_T}{\left(1 - \frac{I_T^d - r}{I_T^d}\eta_h\right)h_T - \left(1 - \frac{I_T^g + r}{I_T^g}\eta_n\right)n_T} > 0. \tag{40}$$

The sign of this expression follows directly from our assumption $1 > \frac{I^d - r}{I^d}\eta_h$ and the stability condition $\left(1 - \frac{I^d - r}{I^d}\eta_h\right)h - \left(1 - \frac{I^g + r}{I^g}\eta_n\right)n > 0$. The key feature to note from equation (40) is that I_T^g is monotonically increasing in i_T^g. Hence, each i_T^g maps into a unique I_T^g.

The preceding implies that the path of the nominal interest rate is known to be given by

$$i_t = \begin{cases} r, & 0 \leq t < T, \\ r + \tilde{\varepsilon}(I_T^g; \bar{\tau}), & t \geq T. \end{cases} \tag{41}$$

In addition, the implied paths for the lending spread and the deposit spread are given by

$$I_t^\ell = I_t^g = \begin{cases} i_0^g - r, & 0 \leq t < T, \\ i_T^g - r - \tilde{\varepsilon}(I_T^g; \bar{\tau}), & t \geq T. \end{cases} \tag{42}$$

$$I_t^d = \begin{cases} \delta r - (1-\delta)I_0^g, & 0 \leq t < T, \\ \delta\left[r + \tilde{\varepsilon}(I_T^g; \bar{\tau})\right] - (1-\delta)I_T^g, & t \geq T. \end{cases} \tag{43}$$

To tie down the time of the crisis it is useful to note that the path for the nominal exchange rate must be continuous, i.e., E cannot jump at T. Letting T^- denote the instant before the run, the discrete change in central bank liabilities at the moment of the crisis T is given by $\Delta m_T \equiv \delta(h_T - h_0)$, which corresponds to the loss in international reserves since

$\Delta f_T = \Delta m_T$.[19] In what follows, we define the size of the loss in reserves as $S_T \equiv m_0 - m_T$. Thus, by definition, $S_T = -\Delta m_T$. Using equation (24) – and taking into account that for $t \geqslant T$, $\bar{\tau} = \varepsilon_T m_T + (\varepsilon_T - i_T^g) z_T$ – we obtain, after suitable manipulation,

$$T = \frac{1}{r} \log \left(\frac{\bar{\tau} + i_0^g z_0 - r S_T}{\bar{\tau} + i_0^g z_0 - r f_0} \right). \tag{44}$$

3.2 Passive interest rate policy: The Krugman case

We have purposely set up our model so that it reduces to a standard Krugman model (with an endogenous labor supply) for the case in which policymakers set the domestic interest rate (i^g) equal to the market interest rate (i), which implies that $I_0^g = I_T^g = 0$. In this case, the banking sector plays no role and the model delivers the standard results that would arise in a model with no banks and a standard labor-leisure choice. We refer to this case as the "passive interest rate policy" case since policymakers choose not to use their ability to engage in an active interest rate defense (which would require setting the domestic interest rate, i^g, above the market rate, i). Notice that $I_0^g = I_T^g = 0$ implies, by (20), that $I_0^\ell = I_T^\ell = 0$ so that firms do not face a premium for having to resort to bank credit.

The following proposition summarizes the results for this Krugman case:

Proposition 1 *Let $I_0^g = I_T^g = 0$ and assume that $\bar{\tau} > r\left[\tilde{n}(0) - (1-\delta)\tilde{h}(\delta r)\right]$. Then, at the time of the crisis (T), the deposit spread I^d rises, but consumption and output remain unchanged.*

Proof. From (20), it follows that $I_0^\ell = I_T^\ell = 0$. Hence, from equations (26) and (28), neither n nor x change at T. The fact that I^d must rise at T follows directly from equation (43) and the assumption that $\bar{\tau} > r\left[\tilde{n}(0) - (1-\delta)\tilde{h}(\delta r)\right]$. This assumption, when combined with

[19] Note that at time T real net domestic credit d^n remains unchanged since both D^n and E are predetermined. Hence, any change in the money base $m(= \delta h)$ is accompanied by an exactly offsetting change in reserves (f).

equation (37), implies that $\tilde{\varepsilon}(0;\bar{\tau}) > 0$. Since I^d rises, equation (8) implies that h falls at T. To see that consumption must remain unchanged at T, note that equation (5) implies that $(c_0 - \zeta x_0^{\nu})^{-1/\sigma} = (c_T - \zeta x_T^{\nu})^{-1/\sigma}$ (recall that, along a perfect foresight path, the multiplier λ remains unchanged). Hence, $c_0 - c_T = \zeta\left(x_0^{\nu} - x_T^{\nu}\right)$. Since $x_0 = x_T$, it follows immediately that $c_0 = c_T$. ■

Proposition 1 shows that at the time of the crisis there is a run out of deposits (and, hence, out of the monetary base, as banks hold cash reserves against deposits). The rise in the deposit spread, I^d, at the time of the crisis reduces the demand for deposits. The fall in deposits reduces the loanable funds available to the banks. Since the lending spread, I^{ℓ}, is unchanged, the demand for loans by firms remains unchanged as well. Given that domestic bonds and loans to firms are perfect substitutes in the commercial banks' asset portfolio, the banks adjust to the lower supply of loanable funds by reducing their holdings of domestic bonds while keeping private lending unchanged. Naturally, these are the same results that would obtain if there were no banking system in the model and households directly held the monetary base.[20]

4 Active interest rate defense

We now turn to the central focus of the paper; namely, the effects of an active interest rate defense of the peg. By "active", we mean deviating from a passive interest rate policy by setting the domestic interest rate (i^g) above the market interest rate (i), which implies setting

[20] Notice that the result that output and consumption remain unchanged at T follows from our assumption that the transactions technology is independent of consumption. If this were not the case, it is easy to show that the rise in I^d at T would lead to lower consumption and lower output. By abstracting from this effect (which we do not need for our results to go through), we ensure that all output effects studied below are the result of an active interest rate defense of the peg.

a positive I^g. (Recall that a passive interest rate policy corresponds to setting $I_t^g = 0$.) We allow the monetary authority to set a piece-wise flat path for i_t^g (i.e., it can set both i_0^g and i_T^g, but not necessarily at the same level). Denoting a passive domestic interest rate by $i^g(p)$, we define the passive interest rate policy path as

$$i_t^g(p) = \begin{cases} r, & 0 \leq t < T, \\ r + \tilde{\varepsilon}(0; \bar{\tau}) & t \geq T. \end{cases} \tag{45}$$

We consider two types of interest rate defense policies. The first policy – referred to as a *contemporaneous* interest rate defense – entails raising i_T^g above the passive level of $i_T^g(p)$ (for a given i_0^g). Note that this amounts to setting a positive I_T^g. In this case, the domestic interest rate is raised at the time of the crisis (although the policy is announced at time 0). The second policy – referred to as a *preemptive* interest rate defense – involves raising i_0^g above $i_0^g(p)$ (for a given i_T^g). In this case, the domestic interest rate is raised *before* the crisis takes place.[21]

4.1 Contemporaneous interest rate defense

We start by investigating the effects of raising i_T^g above the passive level $i_T^g(p)$. The following proposition summarizes the two key effects:

Proposition 2 *The time of the crisis (T) is a non-monotonic function of the post-collapse domestic interest rate i_T^g. In particular, for small increases in i_T^g above $i_T^g(p)$ the crisis is delayed relative to the Krugman case. However, further interest rate increases beyond a threshold level $\hat{i}_T^g$ bring the crisis forward. Furthermore, the higher is i_T^g, the lower is the post-collapse level of output.*

[21] Note that equations (40) and (42) imply that $\frac{\partial I_T^g}{\partial i_T^g} > 0$ and $\frac{\partial I_0^g}{\partial i_0^g} = 1 > 0$. Hence, raising i_t^g above $i_t^g(p)$ implies setting $I_t^g > 0$.

Proof. From (20), we know that $I^{\ell} = I^g$. Hence, from (26), (28) and (40), it follows that both x_T (and thus output) and n_T are decreasing functions of i_T^g. This establishes the last part of the proposition. To prove the non-monotonicity of T in i_T^g, differentiate equation (44) with respect to i_T^g to get

$$\frac{\partial T}{di_T^g} = \left[\frac{-\delta\tilde{h}'(I_T^d)}{\bar{\tau} + i_0^g z_0 - rS_T}\right]\left[\frac{\left(1 - \frac{I_T^g + r}{I_T^g}\eta_n(I_T^g)\right) n_T}{\left(1 - \frac{I_T^d - r}{I_T^d}\eta_h(I_T^d)\right) h_T}\right]\frac{\partial \tilde{I}^g}{\partial i_T^g} \gtreqless 0, \tag{46}$$

where we have used equations (8) and (38). The first term on the right hand side (RHS) above is positive while $\frac{\partial I_T^g}{\partial i_T^g} > 0$ from (40). It can be easily checked that $1 \gtreqless \frac{I_T^g + r}{I_T^g}\eta_n(I_T^g)$ as $1 + \phi I_T^g \lesseqgtr \nu(1 - \phi r)$. Hence, since $1 < \nu(1 - \phi r)$, then $\frac{\partial T}{\partial i^g} > 0$ for low values of i^g but $\frac{\partial T}{\partial I^g} < 0$ for all $I^g > (\nu(1 - \phi r) - 1)/\phi \equiv \hat{I}^g$. Now define $\hat{\imath}^g$ such that $\hat{I}^g = \tilde{I}^g(\hat{\imath}^g; \bar{\tau})$. The proof of the non-monotonicity of T in i_T^g then follows directly from the fact that $\partial \tilde{I}^g / \partial i_T^g > 0$. ■

We have thus shown that by merely announcing at time 0 that domestic interest rates will be raised by more than any increase in the market interest rate, the monetary authority can potentially delay the crisis relative to the Krugman case (i.e., passive interest rate policy). In practice, this ability to postpone the crisis may make all the difference since it gives time to the fiscal authority to put its house in order and therefore prevent the crisis altogether. But this works only up to a point. Beyond a threshold level of the domestic interest rate, any further interest rate hike only succeeds in bringing the crisis forward instead of delaying it.

To understand the non-monotonicity of T note that

$$\frac{\partial T}{\partial i_T^g} = \left(\frac{\delta}{\bar{\tau} + i_0^g z_0 - rS_T}\right)\frac{\partial h_T}{\partial i_T^g},$$

where we have used the fact that $m = \delta h$. Hence, any increase in the post-collapse demand for money (or δh_T) will, *ceteris paribus*, postpone the crisis while any decrease in h_T has the opposite effect. Intuitively, for a given path of reserves pre-collapse, an increase in the post-collapse money demand reduces the size of the attack and, thereby, postpones the time of the attack. The opposite occurs in the event of a decrease in h_T. Recall that the opportunity cost of demand deposits is $I^d \equiv r + \varepsilon - i^d$. A rise in i^g, in and of itself, increases the deposit rate, i^d – recall that $i^d = (1-\delta)i^g$ – and therefore tends to reduce I^d and increase the demand for h_T (the money demand effect). A rising i^g, however, tends to increase the post-collapse inflation rate (and hence I^d) for two reasons. First – and as discussed earlier – there is a direct fiscal effect since the rise in i^g increases the debt service. Second, there is an indirect fiscal effect (associated with the output effect) as a rising i^g also raises I^g, which in turn induces a fall in bank credit to firms, n. This effect tends to reduce fiscal revenues because the counterpart of a falling n is an increase in z (i.e., an increase in liabilities of the central bank held by commercial banks), which increases the government's debt service. In order to finance this fall in revenues, the post-collapse inflation rate (i.e., the rate of depreciation) must increase. These two effects tend to increase I^d. For all $i^g > \hat{\imath}^g$, these two effects dominate and further increases in i^g actually raise I^d.

The negative output effect of a higher i_T^g results from the higher lending spread induced by a higher domestic interest rate. The higher lending spread increases the effective real wage, which lowers demand for labor (and hence output) and leads to a lower demand for bank credit. This induces banks to substitute out of loans and into bonds.

4.2 Preemptive interest rate defense

We now turn to the effects of a preemptive interest rate defense whereby the pre-crisis interest rate is set at a high level (relative to the passive case). Specifically, we investigate the potential trade-offs of setting $i_0^g > i_0^g(p)$. Note that this corresponds to a *temporary* increase in interest rates at date $t = 0$ which is expected to last till date T. Interest rates are expected to revert back to the passive level $i_T^g(p)$ at time $t \geq T$. Hence, we continue to maintain $I^g_T(p) = 0$. The following proposition summarizes the main results:

Proposition 3 *The time of the crisis is potentially a non-monotonic function of the pre-collapse interest rate i^g_0. Thus, for all $i^g_0 \geq \hat{\imath}^g$ the time of the crisis is unambiguously decreasing in i^g_0. However, for small increases in i^g_0 above $i^g_0(p)$, the crisis may be postponed. The pre-crisis demand for real demand deposits is monotonically increasing while the pre-crisis output is monotonically decreasing in i^g_0.*

Proof. From (20), we know that $I^\ell_0 = I^g_0 = i^g_0 - r$. Hence, from (26), it follows that x_0 (and thus output) is decreasing in i^g_0. From (43), it is easy to see that I^d_0 is lower than in the Krugman case (since I^g_0 is higher), and therefore real demand for deposits is higher. This establishes the last part of the proposition.

Using the commercial bank balance sheet relation $z = (1-\delta)h - n$, we can differentiate equation (44) with respect to i^g_0 to get

$$\frac{\partial T}{\partial i^g_0} = \left(\frac{1}{\bar{\tau} + i^g_0 z_0 - rS_T}\right)\left[\frac{\Omega\left(S_T - f_0\right)}{\bar{\tau} + i^g_0 z_0 - rf_0} + \delta(1-\delta)\frac{\partial h_0}{\partial I^d_0}\right],$$

where $\Omega \equiv (1-\delta)\left(1 - \frac{I^d_0 - r}{I^d_0}\eta_h(I^d_0)\right)h_0 - \left(1 - \frac{I^g_0 + r}{I^g_0}\eta_n(I^g_0)\right)n_0 \lesseqgtr 0$. Denoting the instant before the attack by T^-, note that $S_T - f_0 = f_{T^-} - f_0 < 0$ since reserves are secularly declining over time.[22] Moreover, $\frac{\partial h_0}{\partial I^d_0} < 0$. Hence, $\Omega \geq 0$ is a sufficient condition for $\frac{\partial T}{\partial i^g_0} < 0$, i.e., for the crisis to be brought forward in time due to an increase in i^g_0. Recalling that $1 \gtreqless \frac{I^g + r}{I^g}\eta_n(I^g)$ as $I^g \lesseqgtr \hat{I}^g \equiv \left(\nu(1-\phi r) - 1\right)/\phi$, it follows that $\Omega > 0$ for all $i^g_0 \geq \hat{\imath}^g \equiv \hat{I}^g + r$ since $1 > 0 > \frac{I^d_0 - r}{I^d_0}\eta_h(I^d_0)$. For $\Omega < 0$ however, the sign of $\frac{\partial T}{\partial i^g_0}$ is ambiguous. Figure 3 provides a numerical example to show the existence of the case in which there is a range of i^g_0 in which $\frac{\partial T}{\partial i^g_0} > 0$ for small i^g_0 but $\frac{\partial T}{\partial i^g_0} < 0$ for all i^g_0 beyond a threshold point.[23] ■

[22] Since international reserves go to zero at T, the size of the run at T is $S_T = f_{T^-}$.

[23] The key parameter values for the numerical example in Figure 3 are as follows: $i^g_T = 0.25$, $\phi = 0.009$, $r = 0.1$, and $\delta = 0.99$. The vertical axis meaures percentage deviations from the passive interest rate case.

As before, the negative output effects of a higher i_0^g is due to the higher lending spread induced by higher domestic interest rates. At the same time, since the opportunity cost of holding demand deposits falls as i_0^g increases, demand for real demand deposits goes up.

To understand the effect of i_0^g on the time of the attack, note that from equation (44) the initial domestic interest rate affects T through two channels. First, it affects T through the effect on the size of the attack $S_T = m_0 - m_T$. Since $m_0 = \delta h_0$ is monotonically rising in i_0^g, the size of the attack is increasing in i_0^g. Given a path for reserves, a bigger attack at T implies that the attack must happen sooner since the cutoff level for reserves at which the run wipes out remaining reserves is reached sooner. This negative effect on T is captured by the term $\delta(1-\delta)\frac{\partial h_0}{\partial I_0^d}$.

However, there is a second effect of i_0^g on T which comes through the effect on $i_0^g z_0$. It is easy to check that $\frac{\partial i_0^g z_0}{\partial i_0^g} \equiv \Omega$. Note that during the fixed exchange rate period, the fiscal deficit is financed through the loss of international reserves. Since the initial fiscal deficit is $\bar{\tau} + i_0^g z_0 - r f_0$, $\Omega > 0$ implies that the initial deficit rises with i_0^g which, in turn, implies that reserves decline at a faster rate. Hence, for a given S_T the cutoff level of reserves is reached faster and the crisis happens earlier. Thus, when $\Omega > 0$ both effects tend to bring the crisis forward and $\frac{\partial T}{\partial i_0^g}$ is unambiguously negative. For $\Omega < 0$ however, the initial deficit declines as i_0^g rises. Hence, reserves decline at a slower rate which implies that, for a given S_T, the attack must happen later. In this case the fiscal effect and the size of the run effect go in opposite directions. Whether the crisis is postponed or brought forward through an increase in i_0^g depends on the net effect. Figure 3 shows the existence of cases where the fiscal effect can dominate and the attack can be postponed for small increases in i_0^g.

(As should be obvious, this is just a numerical example and there is no attempt at replicating any particular economy.)

5 Optimal interest rate defense

The previous analysis makes clear that while raising interest rates can successfully delay a crisis (up to a point), this beneficial effect comes at the cost of a fall in output. The obvious question then arises: given the preexisting distortion of an initial budget deficit which is inconsistent with a fixed exchange rate, what is the optimal interest rate defense of the peg?

To answer this question, notice that since the paths of consumption and labor may change only at T, household's welfare, given by equation (1), can be expressed as

$$W = \frac{1}{r\left(1 - 1/\sigma\right)} \left\{ [(c_0 - \zeta x_0^{\nu})^{1-1/\sigma} - 1] \left(1 - e^{-rT}\right) + [(c_T - \zeta x_T^{\nu})^{1-1/\sigma} - 1] e^{-rT} \right. . \tag{47}$$

Given that the multiplier λ is constant along any perfect foresight path, first-order condition (5) implies that $c_0 - \zeta x_0^{\nu} = c_T - \zeta x_T^{\nu}$. Combining this with (31), equation (47) can be rewritten as:

$$W = \frac{1}{r\left(1 - 1/\sigma\right)} \left\{ \left\{ [x_0 - \zeta x_0^{\nu} - \psi(h_0)] \left(1 - e^{-rT}\right) + [x_T - \zeta x_T^{\nu} - \psi(h_T)] e^{-rT} \right\}^{1-1/\sigma} - 1 \right\}. \tag{48}$$

Since all endogenous variables in (48) are functions of i_0^g and i_T^g, welfare is maximized by the solution to the following problem:

$$\underset{\{i_0^g, i_T^g\}}{\text{Max}} \, L = [x_0 - \zeta x_0^{\nu} - \psi(h_0)] \left(1 - e^{-rT}\right) + [x_T - \zeta x_T^{\nu} - \psi(h_T)] e^{-rT}, \tag{49}$$

where $x_0 = \tilde{x}(I_0^g)$, $x_T = \tilde{x}(I_T^g)$, $T = \tilde{T}(i_0^g, i_T^g)$, $h_0 = \tilde{h}(I_0^d)$, $h_T = \tilde{h}(I_T^d)$, $I_0^d = \delta r - (1 - \delta) I_0^g$, and $I_T^d = \delta i_T - (1 - \delta) I_T^g$, as follows from (8), (26), (43), and (44). The non-negativity restrictions on I_0^d and I_T^d require imposing the constraint $i_0^g \leq \frac{r}{1-\delta}$ and the restriction that $\bar{\tau} > \left(\hat{I}^d - r\right) \tilde{h}(\hat{I}^d) + (\hat{I}^g + r)\tilde{n}(\hat{I}^g)$ where $\hat{I}^d = \tilde{I}^d(\hat{I}^g, \bar{\tau})$ which implies that $I_T^d = 0$ is not feasible in this economy. Recall that from equation (38) $\frac{\partial \tilde{I}^d}{\partial I_T^g} \lesseqqgtr 0$ as $i_T^g \lesseqqgtr \hat{\imath}^g$ and that

$\hat{I}^g = \tilde{I}^g(\hat{\imath}^g, \bar{\tau}) \equiv (\nu(1-\phi r)-1)/\phi$. Hence, this last condition implies that level of fiscal transfers are so high that the lowest possible value for I_T^d is positive.

Differentiating (49) with respect to i_0^g and i_T^g gives:

$$\frac{\partial L}{\partial i_0^g} = (1-e^{-rT})\left[\frac{\phi I_0^g}{1+\phi I_0^g}\frac{\partial \tilde{x}(I_0^g)}{\partial I_0^g} - (1-\delta) I_0^d \tilde{h}'(I_0^d)\right] + e^{-rT} r \Gamma \frac{\partial \tilde{T}(i_0^g, i_T^g)}{\partial i_0^g}, \tag{50}$$

$$\frac{\partial L}{\partial i_T^g} = e^{-rT}\left[\left(\frac{\phi I_T^g}{1+\phi I_T^g}\frac{\partial \tilde{x}(I_T^g)}{\partial I_T^g} + I_T^d \tilde{h}'(I_T^d)\frac{\partial \tilde{I}^d}{\partial I_T^g}\right)\frac{\partial \tilde{I}^g}{\partial i_T^g} + r\Gamma \frac{\partial \tilde{T}(i_0^g, i_T^g)}{\partial i_T^g}\right], \tag{51}$$

where $\Gamma \equiv x_0 - \zeta x_0^\nu - \psi(h_0) - [x_T - \zeta x_T^\nu - \psi(h_T)]$ and where we have used the first-order conditions for money demand and labor.

To focus on the intuition, consider for a moment interior solutions (i.e., think of (50) and (51) as holding with equality). At an optimum, the government equates the marginal costs and benefits of a higher i_0^g and i_T^g. What are the marginal costs and benefits of increasing i_0^g (i.e., preemptive interest rate defense)? The two terms on the RHS of (50) capture the marginal cost and marginal benefit of raising i_0^g. Consider the first term within the square brackets. A higher i_0^g leads to a higher lending spread (a higher I_0^ℓ). This, in turn, increases the effective real wage and thus reduces labor. Lower labor implies less output (a negative effect) but less disutility from labor (a positive effect). The second (non-negative) term in the square brackets in (50) captures one benefit of raising i_0^g. A higher i_0^g reduces the opportunity cost of holding demand deposits (I_0^d), thus increasing real demand for deposits and reducing transactions costs. The last term on the RHS reflects a second potential benefit of raising i_0^g. If a higher preemptive interest rate delays the crisis, i.e., $\frac{\partial \tilde{T}(i_0^g, i_T^g)}{\partial i_0^g} > 0$, then the good times are prolonged which is welfare improving. The trade-offs induced by a contemporaneous interest rate defense as captured by equation (51) are exactly analogous.[24]

[24] Notice that the benefit from delaying a crisis that is derived through an extension of the good times

Having described the trade-offs implied by an interest rate defense, we now characterize the key features of the optimal interest rate policy.

Proposition 4 *Consider a perfect foresight equilibrium path for a given path of fiscal spending, i.e., $\tau_t = \bar{\tau}$ and an initial fiscal deficit, i.e., $\bar{\tau} - rf_0 > 0$. Given such a path and the announced exchange rate policy, it is always optimal, starting from the passive interest rate case, to set $i_T^g \in (i_T^g(p), \hat{\imath}^g)$. Moreover, the condition $\frac{\partial \tilde{T}(i_0^g, i_T^g)}{\partial i_0^g} \geq 0$ is sufficient (but not necessary) for $i_0^g > i_0^g(p)$.*

Proof. First note that $i_0^g = i_0^g(p)$ and $i_T^g = i_T^g(p)$ correspond to setting $I_0^g = I_T^g = 0$. It is easy to see that evaluating equation (51) around $I_T^g = 0$ gives $\left.\frac{\partial L}{\partial i_T^g}\right|_{i_T^g = i_T^g(p)} > 0$ once we note that $\left.\frac{\partial \tilde{T}(i_0^g, i_T^g)}{\partial i_T^g}\right|_{i_T^g = i_T^g(p)} > 0$ since $\frac{\partial \tilde{T}(i_0^g, i_T^g)}{\partial i_T^g} \gtreqless 0$ as $I_T^g \lesseqgtr \hat{I}^g > 0$. Similarly, evaluating equation (50) around $I_0^g = 0$ gives $\left.\frac{\partial L}{\partial i_0^g}\right|_{i_0^g = i_0^g(p)} > 0$ if $\frac{\partial \tilde{T}(i_0^g, i_T^g)}{\partial i_0^g} \geq 0$ which is the sufficient condition stated in the proposition. Lastly, evaluating equation (51) around $i^g = \hat{\imath}^g$ gives $\left.\frac{\partial L}{\partial i_T^g}\right|_{i_T^g = \hat{\imath}^g} < 0$ since $\left.\frac{\partial \tilde{I}^d}{\partial i_T^g}\right|_{i_T^g = \hat{\imath}^g} = \left.\frac{\partial \tilde{T}(i_0^g, i_T^g)}{\partial i_T^g}\right|_{i_T^g = \hat{\imath}^g} = 0.$ ■

Proposition 4 says that the optimal pre and post-crisis domestic interest rates are higher than the passive interest rate policy implied by the Krugman case. Hence, it is optimal to engage in *some* active interest rate defense. Furthermore, at an optimum for the contemporaneous interest rate policy, it is feasible to delay the crisis further but not optimal to do so.[25]

applies only if $\Gamma > 0$. Otherwise, it reflects a welfare cost. The sign of Γ is, in general, ambiguous and depends on parameters and the optimal policy.

[25] It should be noted that in these Krugman-type first-generation currency crisis models where BOP crises occur due to an unsustainable fiscal stance, the globally optimal policy is to let the exchange rate collapse at time 0 itself, i.e., go to a flexible exchange rate right away. This is true in our model as well. Hence, in Proposition 4 we describe the "constrained" optimal interest rate policy which is contingent on the announced exchange rate policy and fiscal path. In a related paper, Rebelo and Végh (2002) provide a rationale for delaying the collapse of an exchange rate peg in these first-generation models by introducing various costs

Intuitively, around the point $I_T^g = 0$, there is a first-order welfare gain in terms of reducing transaction costs and postponing the crisis but no first-order output loss. The trade-offs involved for the optimal preemptive interest rate defense are similar. The presence of the sufficiency condition for the preemptive case but not for the contemporaneous case simply reflects the fact that under our parameter assumptions the time of the crisis is always increasing in i_T^g around the passive interest rate policy $i_T^g = i_T^g(p)$. However, the absence of a corresponding parameter restriction for the preemptive interest rate policy implies that it is feasible for T to be decreasing in i_0^g around $i_0^g(p)$ – the passive interest rate point. Since $\Gamma|_{i_0^g = i_0^g(p)} > 0$, a falling T implies that a preemptive interest rate defense shortens the good times and therefore reduces welfare. We should, however, stress that this condition is only sufficient and not necessary for the optimality of engaging in some preemptive interest rate defense.

The last part of the proposition also shows that the contemporaneous interest rate policy that maximizes the delay of the balance of payments crisis is not optimal. In particular, the proposition shows that at the point of maximum delay, the policymaker would do better by reducing i_T^g a little and thereby allowing the crisis to happen sooner. Intuitively, at the point of maximum delay, a marginal reduction in i_T^g has only second order effects on the post-collapse demand for deposits (and hence transactions costs and the time of the attack). On the other hand, the reduction in the interest rate reduces the domestic lending spread which has first-order effects on loans and output. Hence, it is not optimal to raise i_T^g all the way to $\hat{\imath}^g$, which is the point where the delay is maximized.

associated with abandoning the peg.

6 Conclusions

The increasing frequency of BOP crises in disparate parts of the world raises the issue of what is the appropriate policy response to such episodes. In this paper we have looked at an often-used tool to fight off speculative attacks – higher interest rates. Higher interest rates typically work by increasing the demand for domestic currency assets – the money demand effect. They carry, however, some adverse side-effects. In particular, policymakers are often concerned about the output consequences of an aggressive interest rate defense of an exchange rate peg.

In this paper we have studied a model in which, by increasing the demand for interest-bearing deposits, higher interest rates have a positive money demand effect, but also extract an output cost by making bank credit more expensive. We have shown that the time of the crisis may be a non-monotonic function of interest rates, which implies that there is some rise in interest rates (both before and at the time of crisis) that maximizes the delay. Furthermore, an optimal interest rate defense involves announcing high interest rates both before and at the time of the crisis. Hence, it is always optimal to engage in *some* active interest rate defense, contrary to the implicit assumption in most of the literature based on Krugman (1979). In conjunction with our previous work (Lahiri and Végh (2003)), where we abstracted from output costs and focused solely on fiscal costs, the results of this paper suggest cause for extreme caution and restraint in the use of higher interest rates as an instrument for defending exchange rate pegs.

As is true with any model, ours simplifies a much more complex reality, in which other mechanisms surely come into play. But it is precisely the complex nature of the real world which, in our view, makes it even more valuable to go back to basics and develop simple models that will hopefully capture some essential trade-offs and provide some guidance to our thinking. As we view the world, there are three key aspects of reality which are not directly captured in our model. First, policymakers use higher interest rates mainly to buy time to put the fiscal house in order. This feature could be captured by assuming that the fiscal fundamentals follow some stochastic process whereby, at each point time, there is some exogenous probability that the fiscal situation will be resolved. This would increase the benefits of postponing the crisis without altering the essential mechanisms. Second, currency crises can lead to a banking crisis, which in turn can worsen the output contraction. This feature could be incorporated along the lines of Burnside, Eichenbaum, and Rebelo (2001b). Finally, we should mention that our framework abstracts from "signalling" considerations (i.e., higher interest rates may convey information about policymakers' ability and/or commitment to defend a peg), which are the focus of Drazen (2003). Since addressing these signalling considerations naturally requires a different theoretical framework, we view Drazen's analysis as complementing ours.

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Figure 1. Output and Interest Rates

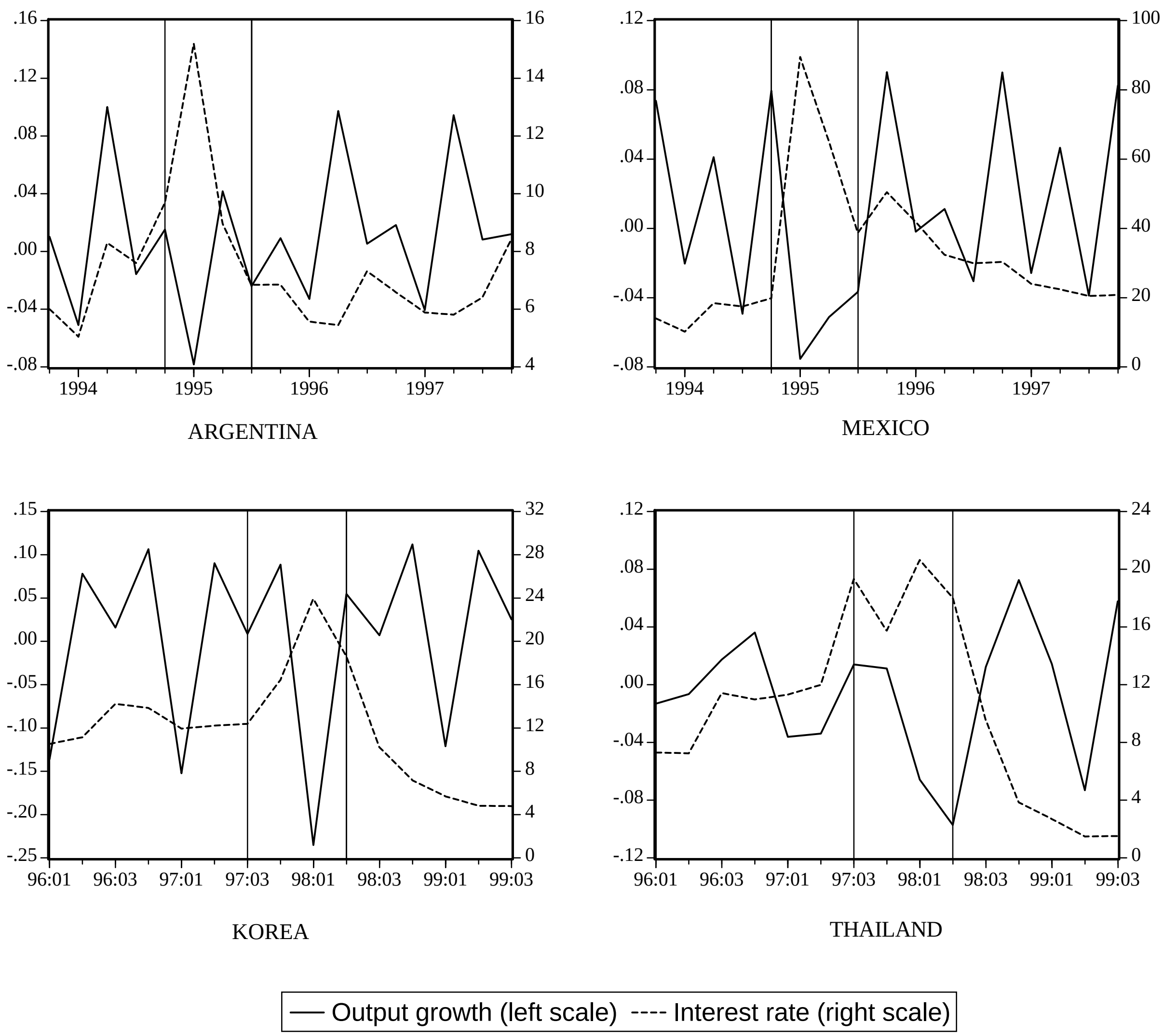

Figure 2. Loans and Interest Rates

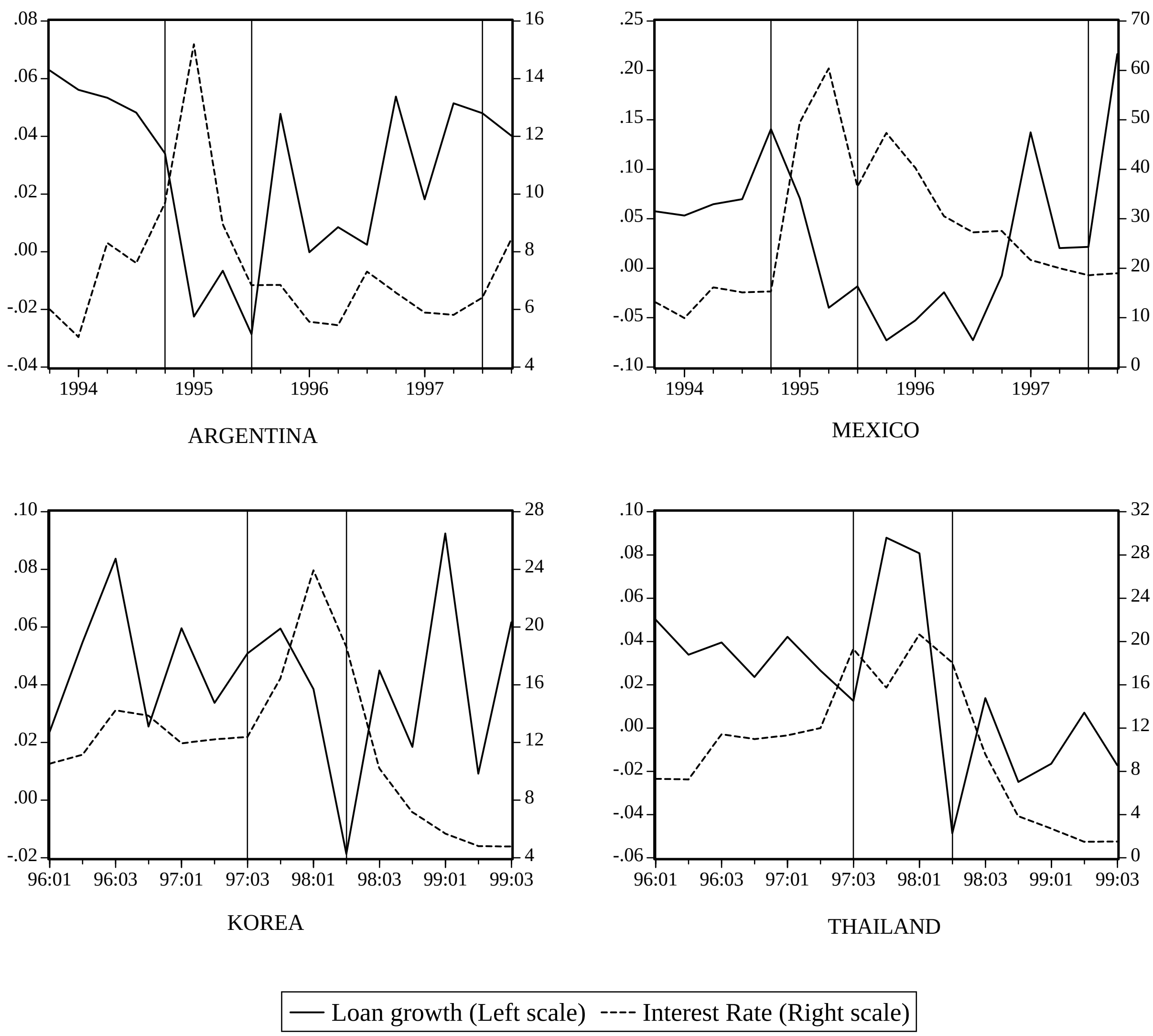

Figure 3. Preemptive interest rate defense