Output Costs, BOP Crises, and Optimal Interest Rate Policy*

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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, Krugman-type 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. Welfare may also be a non-monotonic function of the increase in interest rates. There is in fact a whole range of interest rate increases for which it is feasible to delay the crisis but not optimal to do so. The optimal interest rate policy involves high interest rates before the crisis and a further hike when the crisis takes place. The larger are the output effects, the looser is the optimal interest rate policy, and the sooner should the crisis be allowed to occur.

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1 Introduction

The 1990s witnessed a succession of currency crises, ranging from the EMS crises in 1992 to similar episodes in Mexico (1994), Asia (1997), Russia (1998), and Brazil (1999). 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 (Fischer, 1998), as implemented in Russia, Brazil, and most Asian countries. Whether raising interest rates should be part of a policy package aimed at either preventing or managing currency crises is a matter of intense debate in the policy arena. IMF critics like Jeff Sachs and Joe Stiglitz (former chief economist of the World Bank), for instance, have vehemently argued against high interest rates policies.[1]

The standard rationale among policymakers for raising short-term interest rates is to make more attractive domestic currency denominated assets (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 weakening 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.

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 an incipient crisis, as it implicitly assumes that policymakers sit passively as they watch international reserves dwindle down until the final

[1] See, for example, Sachs (1997, 1999) and Stiglitz (2000).

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 (2000), 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 begin to bring the crisis forward as the fiscal effect begins to dominate the money demand effect. There is thus some increase in interest rates which will maximize the delay. We also show, however, that there is a whole range of interest rate increases for which it is *feasible* to delay a crisis but *not optimal* to do so. In other words, while *some* active interest rate defense is in general optimal, the presence of a fiscal constraint implies that raising interest rates too much may be counterproductive. 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]

This paper shuts down the fiscal channel and focuses instead on the output effect. As Figure 1 illustrates for six emerging economies that have actively defend their currencies by raising short-term interest rates, higher interest rates are typically associated with an output contraction.[4] We ad-

[2]See Drazen (1999a, 1999b), Flood and Jeanne (2000), and Lahiri and Végh (2000). A more extensive empirical literature has so far provided mixed evidence on the effectiveness of using higher interest rates to defend a peg/strengthen the domestic currency (see, in particular, Dekle, Hsiao, and Wang (1999), Kraay (1999), and Zettelmeyer (2000).

[3]Flood and Jeanne (2000) also focus on the fiscal costs of higher interest rates by incorporating an active interest rate defense of a peg in the traditional Krugman-Flood-Garber model. Drazen (1999a, 1999b) focuses on the signalling effects of higher interest rates in a "second-generation" Barro-Gordon type of model.

[4]Using a sample of 20 emerging and industrial countries, Calvo and Reinhart (1999) conclude that the rate of output growth declines by 2.7 percent in the year of the crisis. An IMF (1998) study, covering 50 countries, finds that the average output loss in the year of the crisis is 4.3 percent. More recently, Gupta, Mishra, and Sahay (2000), based on a sample of 125 countries and 278 episodes, also conclude that – with the notable exception of crises in Africa and in countries with low capital mobility – currency crises have been typically contractionary. On the theoretical side, see Rodriguez (1999) for a formalization of the output costs of higher interest rates and Burnside, Eichenbaum, and Rebelo (1999) for a model which generates an output contraction in conjunction with a currency/banking crisis.

dress the trade-off between the money demand effect and the output effect in the context of an otherwise standard, optimizing, small open economy which is prone to Krugman-type crises.[5] To this effect, we incorporate a credit channel a la Bernanke-Blinder (1988, 1992) 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, 1996), we model interest rate policy as the monetary authority's ability to set the interest rate on an interest bearing liability (a 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 postpones 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.

Within this model, we ask two questions: (i) does an active interest rate defense serve to postpone an impending crisis?; and (ii) given the Krugman distortion (i.e., a domestic credit policy which is inconsistent with a fixed exchange rate) what is the optimal interest rate policy? To answer the first question, we distinguish between two types of interest rate policies (both of which are announced as of time zero): 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 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 a contemporaneous defense always succeeds in delaying the crisis, while a preemptive defense does delay the crisis when the output effect is relatively small but raising interest rates beyond a certain point will actually bring forward the crisis. In fact, a preemptive interest rate defense may not even be able to delay the crisis at all (it actually brings it forward!) if the output effect is large enough. This already offers a dramatic illustration of the perils of raising interest rates when output effects are present.

[5] By a Krugman-type crisis, we mean an environment where the central bank has pegged the exchange rate but follows an expansionary domestic credit policy. This inconsistency between the fiscal stance and the exchange rate policy leads to a secular loss of reserves. If reserves cannot fall below a threshold level, then the central bank will be forced to abandon the peg in finite time. Moreover, as shown by Krugman (1979), the end of the regime will also be characterized by a speculative attack on international reserves.

We then tackle the second question regarding the optimal interest rate policy. To illustrate the trade-offs involved, we first show how either a contemporaneous or preemptive interest rate defense raises welfare for low values of interest rates but raising interest rates beyond a certain point may actually begin to decrease welfare as the output effect becomes larger. We then ask the question: what is the time path of the domestic interest rate (before and after the crisis) that maximizes consumers' welfare? As a benchmark, we show that, if the output channel is shut off, it is optimal to implement the Friedman rule and the first best is achieved. This is a useful benchmark because it ensures that any deviation with respect to the Friedman rule will be due solely to the output cost of an active interest rate defense. Implementing the Friedman rule in our set-up requires that the domestic interest rate be in fact raised at the time of the crisis from an already high (in a well-defined sense) pre-crisis level. When the output channel is opened, we show that it is optimal to set domestic interest rates lower (both before and after the crisis) than in the benchmark case, but it is still optimal to hike interest rates at the time of the crisis. In fact, simulations of the model indicate that the stronger the output channel, the lower should be the whole path of domestic interest rates, and the sooner should the crisis be allowed to occur. Raising interest rates beyond this point would delay the crisis but reduce welfare.

The paper proceeds as follows. The next section develops the model, while Section 3 shows the mechanics of a BOP crises for a passive interest rate policy. Section 4 develops the main analytical results regarding the effects of interest rates on output and the timing of the crisis. Section 5 analyzes the welfare effects of higher interest rates and derives the optimal path for the domestic interest rate. Section 6 contains concluding remarks.

2 The Model

Consider a small open economy that is perfectly integrated with the rest of the world in both goods and capital markets. The economy is inhabited by an infinitely-lived representative household which receives utility from consuming a perishable good and disutility from supplying labor. The world price of the perishable 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 a pure (non-liquid) bond. These bonds are denominated in terms of the perishable good and pay 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 of the perishable good, x denotes 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, Mendoza (1991) and Correia, Neves, and Rebelo (1995)). In our case, we adopt these preferences for analytical tractability since it will enable us to derive most of our key results analytically.[6] As a check on the theoretical robustness of our results, we will use simulations in Appendix D to show that similar results hold if standard CES preferences are used.

The consumer uses money for reducing transactions costs. Specifically, the transactions costs technology takes the standard form

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

where s denotes the non-negative transactions costs incurred by the consumer and h denotes interest-bearing demand deposits. This transactions technology is increasing in consumption, decreasing in demand deposits, and strictly convex. Formally, it satisfies the following properties:

$$\begin{aligned}
&\psi \geq 0, \quad \psi_c \geq 0, \quad \psi_h \leq 0, \quad \psi_{hh} > 0, \quad \psi_{hc} < 0, \\
&\psi_{cc}\psi_{hh} - \psi_{hc} \geq 0, \quad \psi_h(.) = 0 \text{ for a finite } h, \\
&\psi = 0 \text{ for the satiation level of } h.
\end{aligned}$$

[6] As will become clear below, the key analytical simplification introduced by GHH preferences is that there is no wealth effect on labor supply.

For a given level of consumption, additional real money balances lower transactions costs but at a decreasing rate. The assumption that $\psi_h(.) = 0$ for a finite 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. Further, perfect capital mobility 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).[7] The flow budget constraint facing the representative household is thus given by

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

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:

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

The household chooses paths for $\{c_t, x_t, h_t\}$ to maximize lifetime utility (1) subject to (2) and (4), taking as given τ, I^d, r, w, Ω^f, Ω^b and $a_{0.}$ The first-order conditions for this problem are given by [8]

$$\begin{aligned}
(c_t - \zeta x_t^\nu)^{-1/\sigma} &= \lambda[1 + \psi_c(c_t, m_t)], && (5)\\
\nu\zeta x_t^{\nu-1} &= \frac{w_t}{1 + \psi_c(c_t, m_t)} && (6)\\
-\psi_h(c_t, h_t) &= I_t^d, && (7)
\end{aligned}$$

where λ is the (time-invariant) Lagrange multiplier associated with constraint (4). Equation (5) is the familiar optimality condition whereby, along a perfect foresight equilibrium path, the marginal utility from consumption is

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

[8] As usual, we assume that $\beta = r$ to eliminate inessential dynamics.

equated to the Lagrange multiplier times the effective price of consumption. The (real) effective price of consumption is the market price, unity, plus the transactions costs incurred in purchasing an additional unit of the good ($\psi_c(c_t, m_t)$). Equation (6) shows that labor supply depends positively on the real wage, w, and negatively on the effective price of consumption. Finally, equation (7) implicitly defines the demand for real demand deposits as a decreasing function of their opportunity cost, I^d, and an increasing function of consumption:

$$\begin{aligned} h_t &= \tilde{h}(c_t, I_t^d), && (8) \\ \tilde{h}_c &= -\frac{\psi_{hc}}{\psi_{hh}} \geq 0, && (9) \\ \tilde{h}_{I^d} &= -\frac{1}{\psi_{hh}} < 0. && (10) \end{aligned}$$

As will become clear below, we do not need real money demand to depend on consumption for our key results to go through. Hence, to keep the analysis tractable (and unless otherwise noticed), we will henceforth focus on the case in which the transactions technology does not depend on consumption (i.e., $\psi_c \equiv 0$). In Appendix B, we will resort to simulations to show that our results still go through when the transactions technology depends on consumption.

2.2 Firms

The representative firm in this economy produces the perishable good using the technology

$$y_t = x_t^\eta, \quad 0 < \eta \leq 1. \tag{11}$$

This technology becomes linear in the special case of $\eta = 1$. We also assume that firms face a "credit-in-advance" constraint to pay for the wage bill. In other words, firms need to borrow from banks to pay the wage bill.[9] Formally, this constraint is given by

$$n_t = \phi w_t x_t, \quad \phi > 0 \tag{12}$$

[9] 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.

where n denotes bank loans.[10] 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 $I^l \equiv i^l - i$ (which is the lending spread), we can write the flow constraint faced by the firm as

$$\dot{a}_t^f = ra_t^f + y_t - w_t x_t(1 + \phi I_t^l) - \Omega_t^f. \tag{13}$$

It is easy to see from equation (13) that $\phi I_t^l w_t x_t (= I_t^l n_t)$ is the additional financial cost incurred by firms due to the fact that they need to borrow from banks to pay the wage bill.[11] Integrating forward equation (13), imposing the standard transversality condition, and using equation (11) gives

$$\int_{t=0}^{\infty} e^{-rt}\Omega_t^f dt = a_0^f + \int_{t=0}^{\infty} \left[x_t^{\eta} - w_t x_t(1 + \phi I_t^l)\right] e^{-rt} dt. \tag{14}$$

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 (14) taking as given the paths for w_t, I_t^l, r and the initial stock of financial assets a_0^f. The first order condition for this problem is given by

$$\eta x_t^{\eta - 1} = w_t(1 + \phi I_t^l). \tag{15}$$

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

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

[10] We should note that the credit-in-advance constraint given by equation (12) holds as an equality only along paths where the lending spread I^l is strictly positive. We will assume that if $I^{\ell} = 0$, this constraint holds with equality.

[11] We should note that the credit-in-advance constraint given by equation (12) holds as an equality only along paths where the lending spread, I^l, is strictly positive. We will assume (without loss of generality) that, if $I^{\ell} = 0$, this constraint also holds with equality.

(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 the government bonds. It also holds required cash reserves, m (high powered money). The bank pays depositors an interest rate of i^d. Thus, the balance sheet identity of the bank implies that $m_t + n_t + z_t = h_t$.[13]

The flow constraint faced by the bank is then given by

$$\Omega_t^b = I_t^l n_t + I_t^d h_t + I_t^g z_t - i_t m_t. \tag{16}$$

Note that since required reserves are non-interest bearing, the opportunity cost of holding required reserves for banks is the foregone nominal interest rate i. Similarly, the net resource gain per unit of lending is I^l when lending to firms and $I^g = i^g - i$ when lending to the government. The net resource gain per unit of deposits is the deposit spread $I^d (= i - i^d)$. Lastly, we assume that the central bank imposes a reserve-requirement ratio $\delta > 0$ on the representative bank. Since required reserves do not earn any interest, at an optimum the bank will not hold any excess reserves. Hence, we must have

$$m_t = \delta h_t. \tag{17}$$

Equation (17) implies that the representative commercial bank's balance sheet identity can be written as

$$(1 - \delta) h_t = n_t + z_t. \tag{18}$$

The representative bank maximizes profits given by equation (16) by choosing sequences of n_t, z_t, h_t and m_t subject to equations (17) and (18) taking as

[12] Commercial bank lending to governments is particular common in developing countries. 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. This phenomenon was so pervasive in some Latin America countries during the 1980's that Rodriguez (1991) aptly refers to such governments as "borrowers of first resort". For evidence, see Rodriguez (1991) and Druck and Garibaldi (2000).

[13] Similar results would go through if we allowed banks to hold foreign bonds in world capital markets as long as banks face a cost of managing domestic assets (along the lines of Edwards and Végh (1997) or Burnside, Eichenbaum, and Rebelo (1999)). Put differently – and as is well-known – some friction needs to exist at the banking level for banks to play a non-trivial role in the credit-transmission mechanism. We chose the specifaction with no foreign borrowing because it is analytically simpler. Moreover, it is not a bad description of commercial banking in most developing countries.

given the paths of I^l, I^d, I^g_t, δ and i. The first order conditions for the banks' optimization problem is (assuming an interior solution)

$$
\begin{aligned}
(1-\delta)\, I^l_t + I^d_t &= \delta i_t, && (19)\\
(1-\delta)\, I^g_t + I^d_t &= \delta i_t. && (20)
\end{aligned}
$$

Conditions (19) and (20) simply say that, at an optimum, the representative bank equates the marginal cost of deposits (RHS) to the marginal revenue from an extra unit of deposits (LHS). To see this, notice that the marginal cost of an extra unit of deposits is the cost of holding required reserves, δi. On the other hand, the marginal revenue from an additional unit of deposits has two components. The first, given by I^d_t, is due to the fact that borrowing from consumers is cheaper for banks (whenever $I^d_t > 0$) than borrowing in the open market. The second, given by either by $(1-\delta)\, I^l_t$ or $(1-\delta)\, I^g_t$, captures the fact that banks can lend a fraction $1-\delta$ of each additional unit of deposits to either firms or to the government.

It is easy to see from equations (19) and (20) that we must have

$$
I^g_t = I^l_t. \tag{21}
$$

This also implies that $i^l = i^g$, i.e., the lending rate to firms must equal the interest rate on government bonds. 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 an interior equilibrium (the only ones we will consider) any change in the domestic interest rate i^g will automatically translate into a rise in the loan rate i^l.

From equation (20), it is also easy to see that the deposit spread, I^d, is given by

$$
I^d_t = i_t - (1-\delta) i^g_t. \tag{22}
$$

Since $I^d = i - i^d$, it follows immediately that we must have $i^d_t = (1-\delta) i^g_t$ for all t. Thus, *ceteris paribus*, a rise in the domestic interest rate i^g must result in a higher deposit rate for consumers and, hence, an increase in demand deposits.

Lastly, we will restrict attention to parameter ranges for which I^d and I^l are non-negative. Thus, we will confine attention to environments where $i^d \leq i \leq i^g$. This restriction is needed to ensure a determinate demand for both loans and demand deposits. Note that this amounts to restricting the relevant interest rates to be in the range $0 \leq i^g - i \leq \delta i^g$.

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, R, and sets the reserve requirement ratio, δ. The fiscal authority also makes lump-sum transfers, τ, to the public. The consolidated government's flow budget constraint is thus given by

$$\dot{R}_t = rR_t + \dot{m}_t + \dot{z}_t + \varepsilon_t m_t + (\varepsilon_t - i^g_t)z_t - \tau_t. \tag{23}$$

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 $(\varepsilon_t - i^g_t)z_t$ in the case of domestic bonds.

Integrating forward (23) and imposing the transversality condition $\lim_{t\to\infty} R_t e^{-rt} = 0$ yields the government's intertemporal budget constraint:

$$\int_0^\infty \tau_t e^{-rt} dt = R_0 + \int_0^\infty \left[\dot{m}_t + \dot{z}_t + \varepsilon_t m_t + (\varepsilon_t - i^g_t)z_t\right] e^{-rt} dt + \triangle(m_T + z_T)e^{-rT}, \tag{24}$$

where the last term on the right-hand side (RHS) allows for the possibility of a discrete change in real liabilities at some time $t = T$.[14] We also assume that $R_0 > 0$.

Let d denote the stock of real domestic credit. Since the monetary authority issues interesting 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:

$$\frac{\dot{D}^n_t}{D^n_t} = \mu_t, \tag{25}$$

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, $\dot{R}_t = \dot{m}_t + \dot{z}_t - \dot{d}_t$, where

[14] Throughout the paper, we denote a discrete change in, say, variable x as $\Delta x_T \equiv x_T - x_{T^-}$. Of course, if real liabilities were to jump at other times as well, this should also be accounted for.

$d^n = D^n/E$. Further, note that $\dot{d}_t^n = (\mu_t - \varepsilon_t)d_t^n$. Using these two facts, equation (23) yields the path of government transfers:

$$\tau_t = rR_t + (\mu_t - \varepsilon_t)d_t^n + \varepsilon_t m_t + (\varepsilon_t - i_t^g)z_t + \dot{z}_t. \tag{26}$$

We should note that every specification of the domestic credit policy will, in turn, imply a specific transfer policy for the government. The two cannot be chosen independent of each other.

At this point, we would need to take a stand on whether (i) the monetary authority moves first – by setting an exogenous path of μ – and the fiscal authority passively accommodates such a path by letting transfers adjust; or (ii) the fiscal authority moves first – by setting an exogenous path of transfers – and the monetary authority accommodates this policy by letting the rate of domestic credit growth adjust. Option (ii) implies that fiscal spending cannot be adjusted. In such a case, higher interest rates on domestic bonds have to be financed with the inflation tax (once reserves go to zero). This is the fiscal cost of an active interest rate defense, which is the focus of Lahiri and Végh (2000). In this paper, we want instead to analyze the trade-off between the money demand effect and the output effect. To this end, we will shut down the fiscal channel by assuming that the monetary authority moves first and fixes the rate of growth of net domestic credit at a constant rate μ.

2.5 Resource constraint

By combining the flow constraints for the consumer, the firm, the bank, and the government (equations (3), (13), (16) and (23)) and using equations (11), (12), and (17), we get the economy's flow resource constraint:

$$\dot{k}_t = rk_t + y_t - c_t - \psi(c_t, h_t), \tag{27}$$

where $k = b + b^f + R$. Note that the RHS of equation (27) is simply the current account. Integrating forward subject to the No-Ponzi game yields

$$k_0 + \int_0^\infty [y_t - c_t - \psi(c_t, h_t)]e^{-rt}dt = 0. \tag{28}$$

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, $R_t = 0$). It is known by all agents at $t = 0$ that, if and when that critical level of reserves is reached, the central bank ceases to intervene in the foreign exchange market and allows 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". As will become clear below, in our a set-up a crisis may or may not be accompanied by a discrete loss in international reserves. (Of course, in the typical Krugman model, a crisis is always accompanied by a discrete loss in reserves.)

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 lets the composition of its liabilities (non-interest bearing monetary base and interest bearing domestic bonds) be market determined. (Alternatively, of course, the central bank could set the composition of its liabilities and let i^g be market determined.) For analytical convenience, we will think of I^g as the policy instrument (recall that, by definition, $I^g = i^g - i$). Given i, the central bank can always set an i^g to implement the desired value of I^g. Setting I^g basically amounts to setting the interest rate differential between government bonds and the market interest rate.[15]

A useful way of thinking about interest rate policy in this model is to derive an interest parity condition between the domestic interest rate (i^g) and the market interest rate (i).[16] Recall that, from equation (22), $(1-\delta)i^g = i^d$. Using (7), it then follows that:

$$i_t^g = \frac{i_t}{1-\delta} - \frac{-\psi_h(h_t)}{1-\delta}. \tag{29}$$

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 $\frac{-\psi_h(h_t)}{1-\delta} > 0$). As expected, the liquidity pre-

[15] With no loss of generality, we will restrict attention to piece-wise flat paths of I_t^g.

[16] This interpretation is in the spirit of portfolio models in this area (see Flood, Garber, and Kramer (1996)) which emphasize the notion that imperfect asset substitutability is needed for the monetary authority to be able to influence domestic interest rates. In such a context, Flood, Garber, and Kramer (1996) study the monetary's authority ability to sterilize the fall in money supply at the time of the crisis. For a related analysis, see Kumhof (1998).

mium is a decreasing function of the stock of demand deposits (recall that $\psi_{hh} > 0$). In other words, what enables the government to set a domestic interest rate which 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., $\psi_h = 0$), then the domestic interest rate could not differ from the adjusted market interest rate.

As will become clear below, a higher rate on domestic bonds paid by the central bank will have two 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. Second, the higher interest rate on government bonds will induce banks to also pay a higher rate on bank deposits (recall (22)). This higher rate on deposits reduces the opportunity cost of holding bank deposits and thus increase demand for bank deposits. By raising money demand, and all else equal, this effect will tend to delay a BOP crisis. We will refer to this as the *money demand effect*.

3 Balance of payments crisis

This section traces out the dynamics leading to a BOP crisis and the macroeconomic effects at the time of the crisis for the case in which there is no attempt on the part of the monetary authority to engage in an active interest rate defense. For analytical convenience, we will assume that $\eta = 1$, which makes the production function linear in labor. For $\eta = 1$, the firm's optimality condition (equation (15)) implies that, in equilibrium, the real wage is given by

$$w_t = \frac{1}{1 + \phi I_t^l}. \tag{30}$$

Equation (30) shows that a higher I^l makes bank credit more expensive for firms which increases production costs and, hence, reduces firms' demand for labor, which lowers the real wage. We can combine equations (6) and (30) to get

$$\nu\zeta x_t^{\nu-1} = \frac{1}{1+\phi I_t^l}, \tag{31}$$

which shows that at an optimum, a higher lending spread must reduce employment, x. Equation (30) implies that equilibrium employment is given by

$$x_t = \left(\frac{1}{\nu\zeta}\right)^{\frac{1}{\nu-1}} \left(\frac{1}{1+\phi I_T^l}\right)^{\frac{1}{\nu-1}}. \tag{32}$$

It is also useful to note that the equilibrium amount of loans in this economy is given by (as follows from (30) and (31) and the fact that $n = \phi wx$)

$$n_t = \phi \left(\frac{1}{\nu\zeta}\right)^{\frac{1}{\nu-1}} \left(\frac{1}{1+\phi I_t^l}\right)^{\frac{\nu}{\nu-1}}. \tag{33}$$

The crucial feature to note from equations (31) and (33) 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.

As is well known from Krugman (1979) and Flood and Garber (1984), the assumption that the central bank expands nominal domestic credit at the same time that it fixes the nominal exchange rate implies that a balance of payments (BOP) crisis is inevitable in this economy. To see this, note that a fixed exchange rate implies that the nominal interest rate is fixed and given by $i_t = r$. Further, by assumption, the path of i^g is flat. Since there is no intrinsic source of dynamics in this economy, I^l and I^g must also remain constant over time. Equations (7) and (20) imply that the consumer demand for deposits, h, and the commercial bank demand for bonds, z, must both remain fixed as long as I^d and I^g remain fixed.

From the central bank balance sheet, it follows that $\dot{R}_t = \dot{m}_t - \dot{d}_t^n$. The fixed exchange rate combined with the domestic credit policy given by (25) implies that $\dot{R}_t = \dot{m}_t - \mu d_t^n$. Since the demand for bank deposits (and hence the derived demand for cash on the part of the banks) is constant along such a path, international reserves must evolve according to

$$\dot{R}_t = -\mu d_0^n e^{\mu t}. \tag{34}$$

Equation (34) shows that along paths with a fixed exchange rate and expanding net domestic credit (i.e., $\mu > 0$), international reserves at the central bank 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. Private agents expect the central bank to allow the exchange rate to float from time T onward, while leaving its domestic credit policy unchanged. Hence they expect that at time T the economy will jump to its long run steady-state with the domestic currency depreciating at the constant rate of monetary expansion, μ.[17] Formally, the expected path for the rate of devaluation/depreciation is given by

$$\varepsilon_t = \begin{cases} 0, & 0 \leq t < T, \\ \mu, & t \geq T. \end{cases} \tag{35}$$

Given (35), the path of the nominal interest rate is known to be given by

$$i_t = \begin{cases} r, & 0 \leq t < T, \\ r+\mu, & t \geq T. \end{cases} \tag{36}$$

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

$$I_t^l = I_t^g = \begin{cases} I_0^g & 0 \leq t < T, \\ I_T^g & t \geq T. \end{cases} \tag{37}$$

$$I_t^d = \begin{cases} \delta r - (1-\delta) I_0^g, & 0 \leq t < T, \\ \delta i_T - (1-\delta) I_T^g, & t \geq T. \end{cases} \tag{38}$$

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. Moreover, the central bank balance sheet dictates that assets must equal liabilities at all times. Since reserves must go to zero at T, central bank assets at that time must equal d_T^n. Since total central bank liabilities at time T are given by δh_T and from the commercial bank's balance sheet we know that $\delta h + z + n = h$, the central bank balance sheet identity at T dictates that we must have

$$\delta h_T = \frac{D_0^n e^{\mu T}}{\bar{E}}, \tag{39}$$

[17] This is a perfect foresight monetary model with no intrinsic dynamics. It can be easily shown that the perfect foresight equilibrium path under flexible exchange rates is stationary with the rate of currency depreciation, ε, being equal to the rate of monetary expansion, μ.

Equation (39) implicitly defines the time of collapse T.

In what follows, we denote all pre-collapse variables by the subscript 0 and post-collapse variables by the subscript 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

$$\Delta m_T \equiv \delta h_{T^-} - \delta h_T, \tag{40}$$

which corresponds to the loss in international reserves since $\Delta R_T = \Delta m_T$.[18] Of course, for internal consistency we need to show that a rise in the nominal interest rate that accompanies a collapse of the fixed exchange rate regime must lead to a fall in the demand for m (or, at least, not lead to a rise in m) along a perfect foresight equilibrium path. This is one of the issues that we analyze next.

Passive interest rate policy: The Krugman case We have set up our model so that it reduces to a standard Krugman model (with an endogenous labor supply) for the case that policymakers set the domestic interest rate (i^g) equal to the market interest rate (i), in which case $I_0^g = I_T^g = 0$. 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 (21), 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 $I_0^g = I_T^g = 0$. Then, at the time of the crisis (T), the deposit spread I^d rises, but consumption and output remain unchanged.*

Proof. From (21), it follows that $I_0^\ell = I_T^\ell = 0$. Hence, from equations (31) and (33), neither n nor x change at T. The fact that I^d must rise at T follows directly from equation (38). Since I^d rises, equation (8) implies

[18] Note that from time T onward, real net domestic credit remains constant since $D^n$and E both rise at the common rate μ.

that h falls at T. Since n remains unchanged while h falls, the bank balance sheet identity immediately implies that z must fall as well.

To see that consumption must remain unchanged at T, note that equation (5) implies that

$$(c_0 - \zeta x_0^{\nu})^{-1/\sigma} = (c_T - \zeta x_T^{\nu})^{-1/\sigma},$$

since along a perfect foresight path the multiplier λ remains unchanged. Hence, $c_0 - c_T = \zeta (x_0^{\nu} - x_T^{\nu})$. 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 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. In terms of Figure 2, the crisis takes place at time T^k, where the superscript k stands for the Krugman case (i.e., passive interest rate policy). Notice, of course, that these are the same results that would obtain if there were no banking system in the model and households held directly the monetary base.

We should also note that the result that output and consumption remain unchanged at the time of the crisis under a passive interest rate policy is a direct result of our assumption that the transactions technology is independent of consumption. As shown in appendix B (Proposition 6), if the transactions technology were non-separable between consumption and deposits then the opportunity cost of consumption would also reflect the cost of holding deposits, I^d. In that event a rise in I^d would change the optimal consumption-leisure allocation at T. In particular, at the time of the crisis there would be a negative labor supply effect which would reduce output and create a recession. This appendix also shows that our main results go through in the non-separable case as well.[19]

[19] The labor supply effect of changes in the distortion of the consumption-leisure allocation is discussed in detail in Lahiri (1996).

4 Delaying the crisis at the cost of an output contraction

We now turn to the central focus of the paper; namely, the effects of an active interest rate defense of the peg. In this set-up, the monetary authority can set a piece-wise flat path for I_t^g (i.e., it sets both I_0^g and I_T^g, but not necessarily at the same level). The next section will focus on determining the *optimal* path of I_t^g. To set the stage, this section examines the main trade-offs involved. In particular, we will focus on whether the monetary authority can delay an impending BOP crisis by actively defending the peg with high domestic interest rates and, if so, at what cost in terms of output. We consider two interest rate policies. The first policy – referred to as a *contemporaneous* interest rate defense – entails setting a positive I_T^g (while keeping I_0^g equal to zero). In this case, domestic interest rates are 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 (for $I_T^g = 0$). In this case, domestic interest rates are raised *before* the crisis takes place.[20]

4.1 Contemporaneous interest rate defense

Suppose that, at $t = 0$, policymakers announce the following path for I_t^g:

$$I_t^g = \begin{cases} 0, & 0 \leq t < T, \\ 0 < \bar{I}_T^g \leq I_T^{g*}, & t \geq T, \end{cases} \tag{41}$$

where I_T^{g*}denotes the value of I_T^g for which $I_T^d = I_0^d$.[21]

The idea behind this policy is that by merely announcing at time 0 that domestic interest rates will be raised when market interest rate increase, the resulting higher future demand for domestic financial assets will postpone the crisis (relative to the Krugman case).[22] The following proposition shows that this policy objective is indeed achieved, but at the cost of an output fall:

[20] Obviously, policymakers can set any path of I_t^g and not necessarily one that involves setting either I_0^g or I_T^g to zero. But examining the two cases just mentioned is all that is needed to convey the basic message.

[21] In other words, from (38), I_T^{g*} is the value of I_T^g that satisfies $\delta i_T - (1-\delta) I_T^{g*} = \delta r$.

[22] I_T^{g*}denotes the value for I_T^g for which I_T^d becomes equal to I_0^d; that is, from (38), I_T^{g*} satisfied $\delta i_T - (1-\delta) I_T^{g*} = \delta r$.

Proposition 2 *Let the path of I_t^g be given by (41). Then, the crisis occurs later than in the Krugman case and is accompanied by a fall in output. Furthermore, the higher is $\bar{I}_T^g$, the longer the crisis is delayed but the larger is the fall in output.*

Proof. From (21), it follows that the path of I^ℓ is also given by (41). Hence, from (31) and (33), it follows that both x (and thus output) and n fall at T. From (38), it follows that for all $\bar{I}_T^g < I_T^{g*}$, I^d rises at T. For $\bar{I}_T^g = I_T^{g*}$, I^d does not change at T. Hence, for all $\bar{I}_T^g < I_T^{g*}$, (8) implies that h falls at T. For $\bar{I}_T^g = I_T^{g*}$, the demand for deposits does not change at T. Hence, since n falls at T, the bank's balance sheet implies that z goes up. In this case, the crisis occurs at the point in time at which reserves reach zero (i.e., there is a crisis but no run). Relative to the Krugman case analyzed in Proposition 1, notice that I_T^d is now lower, which implies that h_T is now higher. It is thus clear from (39) that, when the policy is given by (41), T is larger than in the Krugman case. Hence, the crisis is delayed relative to the Krugman case. When $\bar{I}_T^g = I_T^{g*}$, the maximum delayed is achieved in the sense that the crisis occurs at precisely the point in time at which reserves reach the critical level of zero.

To show that the higher is $\bar{I}_T^g$, the more the crisis is delayed but the larger is the fall in output, differentiate (31) and (33) to obtain (using (15) along with the facts that $I^g = I^l$ and $n = \phi w x$ at all times):

$$\frac{dx_T}{dI_T^g} = -\frac{\phi}{\nu-1}\left(\frac{1}{\nu\zeta}\right)^{\frac{1}{\nu-1}}\left(\frac{1}{1+\phi I_T^l}\right)^{\frac{\nu}{\nu-1}} < 0, \quad \text{for all } I_T^g \in [0, I_T^{g*}], \tag{42}$$

$$\frac{dn_T}{dI_T^g} = -\frac{\phi^2\nu}{\nu-1}\left(\frac{1}{\nu\zeta}\right)^{\frac{1}{\nu-1}}\left(\frac{1}{1+\phi I_t^l}\right)^{\frac{2\nu-1}{\nu-1}} < 0, \quad \text{for all } I_T^g \in [0, I_T^{g*}]. \tag{43}$$

This implies that the more aggressive is interest rate policy (i.e., the higher is I_T^g), the more output will fall at T and the lower is post-crisis credit.[23]

Since I_T^d falls as I_T^g rises, the post-collapse money demand h_T must rise with I_T^g. In particular, from equation (8) we get

$$\frac{dh_T}{dI_T^g} = -(1-\delta)\tilde{h}'(I_T^d) > 0, \tag{44}$$

[23] Of course, since x_0 is invariant with respect to I_T^g, the fall in output at T (equal to $x_0 - x_T$) depends only on x_T. Notice that z_0, n_0, and h_0 are also invariant with respect to I_T^g. On the other hand, it is easy to show that a change in I_T^g does alter the level of pre-crisis consumption, c_0. However, the change in c_0 only affects welfare.

which implies, from (39), that T is also an increasing function of I_T^g.

It is also easy to establish that a rise in I_T^g must cause bond holdings (z_T) to rise. Recall that the commercial bank balance sheet implies that $(1-\delta)h_T = z_T + n_T$. Equations (42) and (44) show that n_T falls while demand deposits h_T rise as I_T^g rises. The rise in total bank assets $z_T + n_T$ that is implied by the rise in h_T in conjunction with the fall in n_T implies that z_T must rise with I_T^g as well ■

We have thus shown that by merely announcing that domestic interest rates will be raised whenever market interest rates increase, the monetary authority can delay the crisis relative to the Krugman (i.e., passive interest rate policy) case. In terms of Figure 2, this implies that the crisis will happen for $T > T^k$. In fact, policymakers can delay the crisis all the way up to point T^* where there will not be a final speculative attack (i..e, there is a crisis, in that the monetary authority must abandon the fixed exchange rate, but no run). 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.[24]

Intuitively, the real effects of a higher I_T^g arise due to the higher lending spread that is induced by higher domestic interest rates. The higher lending spread reduces loan demand and, hence, employment and output. This induces banks to substitute out of loans and into bonds. A competitive banking system implies that the higher returns on bank assets is also reflected in a higher deposit rate for households which, in turn, increases deposits with the banking system. In effect, domestic bond holdings rise by more than the fall in bank loans since the banks also use the higher deposits to hold more government bonds. Note that while the banks are indifferent between lending to firms and lending to the government, the higher lending rate implies that the demand for loans by firms becomes smaller.

Figure 3 illustrates Proposition 2 by simulating the model.[25] The time unit is year. For this parametrization, $I_T^{g*} = 0.075$. In other words, when $I_T^g = 0.075$, then $I_T^d = I_0^d = 0.024$. Figure 3 then shows how T, the fall in

[24] We could introduce this feature in the model in a simple way by assuming that at any point in time there is a certain (exogenous) probability that the fiscal authority solve its underlying problems. In such a setting, delaying might avert a crisis altogether. (In a more complex setting, this probability could be endogeneized along the lines of Guidotti and Végh (1999).)

[25] Details of the simulation (which is done for qualitative purposes only and does not attempt to replicate any particular episode or country) can be found in appendix A.

m at T (which captures the final speculative attack), the fall in output at T, and welfare (discussed below) behave as I_T^g is varied from 0 to 0.075. As expected, T is a strictly function of I_T^g, with – in terms of the correspondence with Figure 2 – $T(I_T^g = 0) = T^k$ and $T(I_T^g = I_T^{g*} = 0.075) = T^*$. Panel B (fall in m) shows that for $I_T^g = 0.075$ there is no run. As shown in Panel C, this delay is achieved at the cost of an increasing fall in output, which already suggests that it may not be optimal to delay the crisis as much as it is feasible to do (i.e., up to point T^* in Figure 2).

4.2 Preemptive interest rate defense

In this model, policymakers can also attempt to defend the peg by raising interest rates before the crisis occurs. To isolate the effects of such a policy, suppose that, at time 0, policymakers announce the following path for I_t^g:

$$I_t^g = \begin{cases} 0 < \bar{I}_0^g \leq I_0^{g*}, & 0 \leq t < T, \\ 0, & t \geq T, \end{cases} \tag{45}$$

where $I_0^{g*}$is the value of I_0^g that implies that $I_0^d = 0$ [26]

In studying this case, the assumption that the transactions technology does not depend on consumption turns out to be critical. In this case, increases in I_0^g do not affect T (but would reduce output anyway, as can be easily seen). Therefore, we will consider the general case in which the transactions technology does depend on consumption and use simulations to illustrate the main effects. The following proposition summarizes the results.

Proposition 3 *Let the path of I_t^g be given by (45). Then, for small values of $\bar{I}_0^g$, the crisis occurs later than in the Krugman case, but at the cost of a pre-crisis contraction (relative to the Krugman case). Further raising domestic interest rates, however, may actually bring forward the crisis.*

Proof. We have established existence of all cases discussed below by simulating the model. The appendix discusses the effects of I_0^g on x_0 and shows under what conditions x_0 is a decreasing/increasing function. ■

Intuitively, the effect of a higher I_0^g on T can be thought of as consisting of two separate effects: the money demand effect and the output effect. To isolate the money demand effect, suppose that $\phi = 0$ (no output effect).

[26] From (38), $I_0^{g*} = \frac{\delta}{1-\delta} r$.

Then a higher I_0^g implies a lower I_0^d; that is, the opportunity cost of holding demand deposits is lower. As a result, pre-crisis demand for deposits is higher, which implies lower pre-crisis transaction costs. Since the present discounted value of transactions costs falls, both pre-crisis (c_0) and post-crisis consumption (c_T) increase. The higher post-crisis level of consumption raises post-crisis real demand for deposits, which tends to delay the crisis (i.e., tends to increase T). Hence, the money demand effect tends to postpone the crisis. In and of itself, this money demand effects tends to increase pre-crisis output, by reducing the effective price of consumption (which induces households to consume more and work more).

The output effect, however, goes in the opposite direction. All else equal, a higher ϕ implies that the recessionary impact of I_0^g on pre-crisis output is larger. This tends to reduce the present discounted value of output, reducing both pre- and post-crisis consumption. The fall in post-crisis consumption tends to bring forward the crisis. The output effect tends to depress pre-crisis output.

All else equal, whether the money demand effect or the output effect dominates will depend on the magnitude of ϕ. For small values of ϕ, the output effect will be small and therefore the money demand effect will prevail. In this case, raising interest rate will always delay the crisis. For larger values of ϕ, however, the output effect becomes more important. It then becomes possible that, as interest rates becomes higher, the output effect will more than offset the money demand effect and further raising interest rates will actually bring the crisis forward. Such a case is illustrated in Figure 4. As shown in Panel A, increasing domestic interest rates by a small amount does delay the crisis. Soon, however, the delay is maximized and further raising interest rates begins to bring forward the crisis. In fact, raising interest rates too much implies that the crisis would occur even before it would occur in the Krugman case (i.e., in terms of Figure 2, the crisis would occur for $T < T^k$).[27] Finally, Panel C shows that pre-crisis labor (and, hence, output) falls in response to higher domestic interest rates, as the output effect is large enough to more than offset the money demand effect. (Panel D will be discussed below.)

[27] For even larger values of ϕ, raising interest rates would bring forward the crisis even for small increases in interest rates due to the large output effect.

5 Optimal interest rate policy

Having analyzed the ability of higher domestic interest rates in delaying a crisis (albeit at the cost of a recession), we now turn to the issue of whether an active interest rate defense of a peg is optimal or not. Clearly, even when raising domestic interest rates succeeds in delaying the crisis, it is not obvious at all that it is optimal to do so. To illustrate this fact – and before turning to a formal analysis of optimal interest rate policy – consider panel D in Figures 3 and 4. In the case of contemporaneous interest rate defense (Figure 3), we see that raising I_T^g relative to the Krugman case is welfare improving. However, beyond a certain point, further raising interest rates is not optimal (i.e., welfare decreases) even though the crisis is further delayed. This illustrates the fact that even when it is *feasible* to delay a crisis, it may *not be optimal* to do so. The same is true in the case of preemptive interest rate defense (Figure 4). In this case, there is also a range of interest rate increases for which it is feasible but not optimal to delay the crisis. The obvious questions then arises: given the Krugman distortion (i.e., given a path of domestic credit growth which is inconsistent with the fixed exchange rate), what is the path of domestic interest rates that maximizes households' welfare?

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

$$W = \frac{1}{r\left(1-1/\sigma\right)}\left\{[(c_0-\zeta x_0^{\nu})^{1-1/\sigma}-1]\left(1-e^{-rT}\right)+[(c_T-\zeta x_T^{\nu})^{1-1/\sigma}-1]e^{-rT}\right. . \tag{46}$$

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 (28), (46) can be rewritten as:

$$W = \frac{1}{r\left(1-1/\sigma\right)}\left\{\left\{[x_0-\zeta x_0^{\nu}-\psi(h_0)]\left(1-e^{-rT}\right)+[x_T-\zeta x_T^{\nu}-\psi(h_T)]e^{-rT}\right\}^{1-1/\sigma}-1\right\}. \tag{47}$$

Since all endogenous variables in (47) are functions of I_0^g and I_T^g, we can formally write the government's problem as:

$$\underset{\{I_0^g,I_t^g\}}{\text{Max}}\ [x_0-\zeta x_0^{\nu}-\psi(h_0)]\left(1-e^{-rT}\right)+[x_T-\zeta x_T^{\nu}-\psi(h_T)]e^{-rT}$$

where

$$\begin{aligned}
x_0 &= \tilde{x}_0(I_0^g), \\
x_T &= \tilde{x}_T(I_T^g), \\
T &= \tilde{T}(I_T^d), \\
h_0 &= \tilde{h}_0(I_0^d), \\
h_T &= \tilde{h}_T(I_T^d), \\
I_0^d &= \delta r - (1-\delta) I_0^g, \\
I_t^d &= \delta i_T - (1-\delta) I_T^g,
\end{aligned}$$

as follows from (8), (20), (31), and (39) (and recall that $\psi_c \equiv 0$).

The first-order conditions for this problem are given by:

$$(1-\zeta x_0^{\nu-1})\frac{-d\tilde{x}_0(I_0^g)}{dI_0^g} = -(1-\delta)\psi_h(h_0)\frac{-d\tilde{h}_0(I_0^d)}{dI_0^d}, \tag{48}$$

$$(1-\zeta x_T^{\nu-1})\frac{-d\tilde{x}_T(I_T^g)}{dI_T^g} = -(1-\delta)\psi_h(h_T)\frac{-d\tilde{h}_T(I_T^d)}{dI_T^d} + r\Gamma\frac{d\tilde{T}(I_T^d)}{dI_T^g}, \tag{49}$$

where $\Gamma \equiv x_0 - \zeta x_0^{\nu} - \psi(h_0) - [x_T - \zeta x_0^{\nu} - \psi(h_T)]$.

At an optimum, the government equates the marginal costs and benefits of higher I_0^g and I_T^g. What are the marginal costs and benefits of increasing I_0^g? The term on the LHS of (48) captures the marginal cost of raising I_0^g. Specifically, 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). In equilibrium, however, the output effect prevails (or, at most, the two effects exactly cancel each other), so that the term on the LHS of (48) is either positive or zero.[28] The term on the RHS of (48) captures the 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 transaction costs. Hence, condition (48) says that it is optimal to raise I_0^g up to the point at which the marginal benefit of reduced transactions costs equals the marginal cost of a lower labor supply.

[28] Notice that, from (31), it follows that for $\phi = 0$, $1-\zeta\nu x_0^{\nu-1} = 1-\zeta\nu x_T^{\nu-1} = 0$. For $\phi > 0$, then $1-\zeta\nu x_0^{\nu-1} > 0$ and $1-\zeta\nu x_T^{\nu-1} > 0$.

What are the marginal costs and benefits of increasing I_T^g? The same two effects just discussed still hold. In other words, the LHS in equation (49) captures the marginal cost (in terms of reduced output net of the lower disutility of labor) of a higher I_T^g. Similarly, the first term on the RHS indicates the benefits of reduced transactions costs due to a lower I_T^d. There is, however, a third effect captured by the second term on the RHS of (49). By lowering I_T^d, a higher I_T^g delays the crisis which prolongs the good times and is therefore welfare improving.[29]

5.1 Benchmark case: no output costs

The natural benchmark is the case in which $\phi = 0$. In this case, firms need not resort to bank credit to pay the wage bill and therefore the output channel is shut off. The optimal interest rate policy is stated in the following proposition.

Proposition 4 *Let $\phi = 0$. Consider a perfect foresight equilibrium path for a given path of the nominal interest rate, i_t, given by (36). Given such a path for i_t, the optimal path for I_t^g is given by:*

$$I_0^g = r\frac{\delta}{1-\delta}, \tag{50}$$

$$I_T^g = i_T\frac{\delta}{1-\delta}. \tag{51}$$

This policy achieves the first-best equilibrium. When the crisis occurs there is no run.

Proof. From (20), it follows that setting (50) and (51) implies that $I_0^d = I_T^d = 0$. Hence, it is easy to check that the optimality conditions (48) and (49) are satisfied. Since households are satiated with real demand deposits, transactions costs are zero, and the first best equilibrium is achieved. ■

The intuition behind this proposition is straightforward. When $\phi = 0$, the only distortion present in this economy is the fact that if the opportunity cost of holding demand deposits is positive (as opposed to zero), the private

[29]Notice that if both $\phi = 0$ and $I_0^d = I_T^d$, then $\Gamma = 0$. At this point, there is no difference between the good times (pre-crisis) and bad times (post-crisis) and hence the marginal benefit of delaying is nil.

sector will not hold the socially-optimal level of real demand deposits. It is thus clear that it is optimal for the government to implement the Friedman rule, which implies setting $I_0^d = I_T^d = 0$. To achieve this, I_0^g and I_T^g need to be set at the levels indicated by (50) and (51). By so doing, the government is able to fully offset the non-flat path of i_t and the first-best equilibrium is achieved. The optimal interest rate policy thus involves a hike in domestic interest rates at T.

Since the opportunity cost of holding demand deposits does not change at T, nor does the demand for bank deposits. This implies that, at the time of the crisis, there is no run. In other words, the crisis is going to occur at the point in time at which international reserves reach zero (a point like T^* in Figure 2). Hence, in the absence of output costs, it is optimal to maximize the delay.

5.2 Output costs

Having a well-defined benchmark case, we can now ask the question: what is the optimal path of I_t^g when output cost are present? (i.e., when $\phi > 0$?) The main result is as follows.

Proposition 5 *Let $\phi > 0$. Consider a perfect foresight equilibrium path for a given path of the nominal interest rate, i_t, given by (36). Given such a path for i_t, it is always optimal to deviate from the Friedman rule; that is, it is optimal to set domestic interest rates lower than in the absence of output costs.*

Proof. . See appendix C ■

Proposition 5 says that, in the presence of output costs, it is *not* optimal to implement the Friedman rule. Intuitively, implementing the Friedman rule would eliminate the distortion on money demand but would imply a first-order distortion on the path of labor. This cannot be an optimum because there is no first-order welfare loss associated with marginally increasing the opportunity cost of holding demand deposits, while there is a first-order welfare gain from reducing the labor supply distortion.

Of course, it is still true that setting the Friedman rule maximizes the delay. Doing so, however, is not optimal due to the output cost associated with higher interest rates. Hence, even though it is feasible to further delay the crisis, it is not optimal to do so.

5.3 Effects of higher output costs on optimal interest rate policy

It seems intuitive that, as ϕ is increased, we would expect the optimal domestic interest rates to become lower and the optimal T to become smaller as well. In other words, the higher the output costs, the more costly it is to delay the crisis (even though it is, of course, always feasible to do so), which makes it optimal for the monetary authority to be less aggressive in raising interest rates and let the crisis occur sooner. In order to check these conjectures, we resorted to simulations of the model.

Figure 5 shows how the *optimal* values of I_0^g, I_T^g, and T vary with ϕ. As we already know from Proposition 4, for $\phi = 0$, the optimal policy consists in implementing the Friedman rule, which in this case requires setting $I_0^g = 0.06$ and $I_T^g = 0.135$. In the absence of output costs, therefore, it is optimal for the monetary authority to pay a positive premium for government bonds and then at the moment of the crisis raise this premium even further. As the value of ϕ increases, however, the output cost of an active interest rate defense go up. Hence, the optimal values of both I_0^g and I_T^g decrease with ϕ, as shown in panels A and B. In other words, the higher is ϕ, the less aggressive is the optimal interest rate policy. As a result, the optimal value of T (i.e., the moment in time at which the crisis will take place when the optimal interest rate policy is in place) is also a decreasing function of ϕ, as shown in Panel C. In other words, as output costs become higher, it is optimal to let the crisis occur sooner.

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. However, they also come with some adverse side-effects. In particular, policymakers are often concerned about the fiscal and output consequences of an aggressive interest rate defense of an exchange rate peg.

In this paper we have studied a model where higher interest rates do indeed have a positive money demand effect but they also extract an output cost. The key transmission mechanism through which interest rates have output effects is the credit channel. Banks require deposits to produce loans while firms need bank loans to pay the wage bill. Since loans to firms and domestic government bonds are perfect substitutes in the commercial banks' portfolio, a higher interest rate on domestic bonds increases the lending spread. This reduces employment and results in a contraction in output. The positive money demand effect arises from the fact that higher domestic interest rates also induce a higher deposit rate which increases the demand for deposits (and, hence, money).

On the positive side, we have shown that raising interest rates typically helps in postponing a crisis but that, in the case of a preemptive interest rate defense, raising interest rates beyond a certain point may actually bring the crisis forward. The reason is that the negative effect on money demand of an output contraction may more than offset the positive money demand effect. This result thus calls attention to the fact that, due to the recessionary effects, higher interest rates may at times not even help in delaying a crisis (and, hence, buying time to address the underlying bad fundamentals). On the normative side, we show that the presence of output costs implies that the optimal interest rate defense of the peg is less aggressive than it would otherwise be. Hence, the higher are output costs, the lower should domestic interest rates be and the sooner should the crisis be allowed to occur. The results are particularly striking in that they suggest that while small increases in interest rates may be welfare enhancing, once interest rates become high enough it may not be optimal to raise interest rates any further even though the central bank can successfully postpone a crisis by doing so.

In previous work (Lahiri and Végh (2000)) we have examined the trade-off between the positive money demand effect of higher interest rates and the negative inflationary effect due to the higher fiscal burden generated by such policies. Our finding in that paper was also that the welfare effects of higher interest rates can easily be non-monotonic – with welfare improving for low degrees of interest rate activism but falling for higher degrees of activism. When those results are viewed in conjunction with the results of this paper they suggest cause for extreme caution and restraint in the use of higher interest rates as an instrument for defending exchange rate pegs. While some (low) degree of interest rate defense may be desirable, an overly aggressive interest rate policy may be counterproductive.

Appendices

A Simulation of the model

This appendix provides details on the simulations reported in the text. We assume that money demand follows the Cagan specification. As is well known, the Cagan money demand functions arises from the following transactions cost function:

$$\psi(c,h) = c^q[\kappa - F(h - G\log h)], \tag{52}$$

where $q(\geq 0)$, $\kappa(>0)$, F (>0) and G (>0) are parameters. The parameter κ is just a constant which ensures that, in equilibrium, transactions costs are non-negative.

A.1 Transactions technology does not depend on consumption

If $q = 0$, then it follows from (52) that the transactions technology does not depend on consumption. This is the case formally analyzed in the text. In this case, the demand for deposits (equation (8)) reduces to:

$$h = e^{\frac{F-G}{G}} e^{-\frac{I^d}{G}}. \tag{53}$$

Note that $1/G$ is the (constant) semi-elasticity of h with respect to the opportunity cost I^d of holding deposits.

The common parametrization underlying Figure 3 and 5 is given by:

$$\begin{aligned} r &= 0.04, \quad F = G = 10, \quad \kappa = 10.75, \quad \zeta = 0.9, \\ \sigma &= 0.5, \quad \nu = 1.1, \quad \delta = 0.6, \quad \eta = 1, \quad d_0^n = 0.58. \end{aligned} \tag{54}$$

For Figure 3, $\phi = 0.04$. For Figure 5, ϕ varies in the interval $[0, 1.5]$.

A.2 Transactions technology depends on consumption

If $q > 0$, then the transactions technology (52) (and, hence, the demand for deposits) depends on consumption. In this case, the demand for deposits takes the form:

$$h = e^{\frac{F-G}{G}} e^{-\frac{I^d}{Gc^q}}$$

The parametrization underlying Figure 4 is the same given in (54) and, in addition, $q = 0.0025$ and $\phi = 0.008$.

To check the robustness of the results depicted in Figure 3 and 5 to the assumption that $q = 0$, we ran simulations for the $q > 0$ case for the scenarios discussed in the text and presented in Figures 3 and 5. The results (not shown to conserve in space but available from the authors upon request) were qualitatively the same.

B General transactions costs technology

For analytical simplicity, the text dealt mostly with the case in which the transactions technology (2) does not depend on consumption. This appendix derives some analytical results for the case in which the transactions technology does depend on consumption and the transactions technology is homogeneous of degree one:

$$s_t = c_t v(\frac{h_t}{c_t}), \tag{55}$$

$$v \geq 0,\ v' \leq 0,\ v'' > 0,$$

$$v' = 0 \text{ for a finite value of } \frac{h}{c},\ v = 0 \text{ for the satiation level of } \frac{h}{c}. \tag{56}$$

For this specification, notice that the households' optimality conditions reduce to:

$$(c_t - \zeta x_t^{\nu})^{-1/\sigma} = \lambda p(I_t^d), \tag{57}$$

$$\nu\zeta x_t^{\nu-1} = \frac{w_t}{p(I_t^d)}, \tag{58}$$

$$-v'(\frac{h_t}{c_t}) = I_t^d \Rightarrow\ h_t = c_t L(I_t^d),\quad L'(I_t^d) < 0, \tag{59}$$

where $p(I_t^d)$ denotes the effective price of consumption and is defined as:

$$
\begin{aligned}
p(I_t^d) &\equiv 1 + v[L(I_t^d)] - v'[L(I_t^d)]L(I_t^d) \geq 1, \\
p'(I_t^d) &= -v''[L(I_t^d)]L'(I_t^d)L(I_t^d) > 0.
\end{aligned}
$$

The homogeneity of degree one implies that the effective price of consumption depends only on the opportunity cost of holding demand deposits (I^d).

The following proposition shows that in the Krugman case (i.e., the case in which $I_0^g = I_T^g = 0$), the crisis at time T is accompanied by a fall in output and consumption.

Proposition 6 *Let (i) the transactions technology be given by (55) and (ii) $I_0^g = I_T^g = 0$. Then, at the time of the crisis (T), the deposit spread I^d rises and consumption and output fall.*

Proof. The fact that I^d must rise at T follows directly from equation (38). Hence, $p(I_T^d) > p(I_0^d)$. As a result, it immediately follows from (58) that $x_0 > x_T$. In other words, output falls at T. From (5), it follows that

$$
\left(\frac{c_0 - \zeta x_0^\nu}{c_T - \zeta x_T^\nu}\right)^{1/\sigma} = \frac{p(I_T^d)}{p(I_0^d)} > 1,
$$

since along a perfect foresight path the multiplier λ remains unchanged. Hence,

$$
c_0 - \zeta x_0^\nu > c_T - \zeta x_T^\nu.
$$

Since $x_0 > x_T$, the last inequality implies that $c_0 > c_T$. ■

Intuitively, the rise in the effective price of consumption at time T makes consumption relatively more expensive (relative to leisure). Hence, households choose to consume less and enjoy more leisure (i.e., work more).

Preemptive interest rate defense Consider now the effects of a small change in I_0^g (for an unchanged I_T^g). From (31), it follows that

$$
\begin{aligned}
\frac{dx_0}{dI_T^g} &= \frac{-1}{\zeta\nu(\nu-1)x_T^{\nu-2}\Psi^2}\left\{\phi[1+p(I_0^d)] - p'(I_0^d)(1-\delta)(1+\phi I_0^g)\right\}, \quad (60) \\
\text{where } \Psi &\equiv (1+\phi I_0^g)[1+p(I_0^d)].
\end{aligned}
$$

It follows from (60) that

$$\frac{dx_0}{dI_T^g} > 0 \text{ iff } \phi[1+p(I_0^d)] < p'(I_0^d)(1-\delta)(1+\phi I_0^g),$$
$$\frac{dx_0}{dI_T^g} < 0 \text{ iff } \phi[1+p(I_0^d)] > p'(I_0^d)(1-\delta)(1+\phi I_0^g).$$

This shows that, for low values of ϕ, output is an increasing function of I_T^g, while for high values of ϕ output is a decreasing function of I_T^g.

C Proof of proposition 5

We will show that one can always find a value of ϕ (> 0) for which it is optimal to deviate from the Friedman rule. Evaluating conditions (48) and (49) for $\phi > 0$ around the Friedman rule yields:

$$\left.\frac{\partial W}{\partial I_0^g}\right|_{I_0^d=I_T^d=0} = (1-e^{-rT})(1-\zeta x_0^{v-1})\frac{d\tilde{x}_0(I_0^g)}{dI_0^g} < 0 \qquad (61)$$

$$\left.\frac{\partial W}{\partial I_T^g}\right|_{I_0^d=I_T^d=0} = e^{-rT}\left[r\Gamma\frac{d\tilde{T}(I_T^d)}{dI_T^g} + (1-\zeta x_T^{\nu-1})\frac{d\tilde{x}_T(I_T^g)}{dI_T^g}\right] \qquad (62)$$

Since the term in square brackets on the RHS of (62) depends only on parameters, it is easy to show that one can always pick a value of ϕ for which $\left.\frac{\partial W}{\partial I_T^g}\right|_{I_0^d=I_T^d=0} < 0$.

D CES preferences

We now show that the results derived in the main text for GHH preferences hold for standard CES preferences. This provides a theoretical check of the robustness of our results.

Let preferences now be given by:[30]

[30] Unless otherwise noticed, we keep the same notation as in the main text.

$$
\begin{aligned}
W &= \int_0^\infty \frac{[u(c_t,\ell_t)]^{1-\frac{1}{\sigma}}-1}{1-\frac{1}{\sigma}} e^{-\beta t}dt \qquad (63)\\
\text{where } u(c_t,\ell_t) &\equiv \left[\xi c_t^{\frac{\omega-1}{\omega}} + (1-\xi)\ell_t^{\frac{\omega-1}{\omega}}\right]^{\frac{\omega-1}{\omega}},
\end{aligned}
$$

where ℓ_t denotes leisure, σ is the intertemporal elasticity of substitution, and ω is the elasticity of substitution between consumption and leisure. We also assume that $\omega > \sigma$.[31] The time endowment of the household is normalized to unity. The households' lifetime constraint is therefore still given by (4) (with $x_t = 1 - \ell_t$). The optimality conditions for this problem are given by (7) and:

$$
\begin{aligned}
[u(c_t,\ell_t)]^{\frac{1-\frac{\omega}{\sigma}}{\omega}} \psi c_t^{-\frac{1}{\omega}} &= \lambda, \qquad (64)\\
\frac{\xi}{1-\xi}\left(\frac{\ell_t}{c_t}\right)^{\frac{1}{\omega}} &= \frac{1}{w_t}, \qquad (65)
\end{aligned}
$$

It is easy to check that in the Krugman case, this specification leads to a BOP crisis in which both output and consumption fall. Figure 6 presents a typical simulation of this model, which carries out the same exercise illustrated in Figure 5 for the GHH preferences. The basic parametrization is the same as in (54) (except for the preferences parameters) and, in addition, $\sigma = 0.3$, $\omega = 0.5$, and $\xi = 0.5$. As is clear from the picture, the same qualitative results obtain. In other words, in the presence of output costs, it is not optimal to maximize the delay. Further, the higher the output costs, the less aggressive the optimal interest rate policy, and the sooner should the crisis be allowed to occur.

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Figure 1. Interest rates and GDP

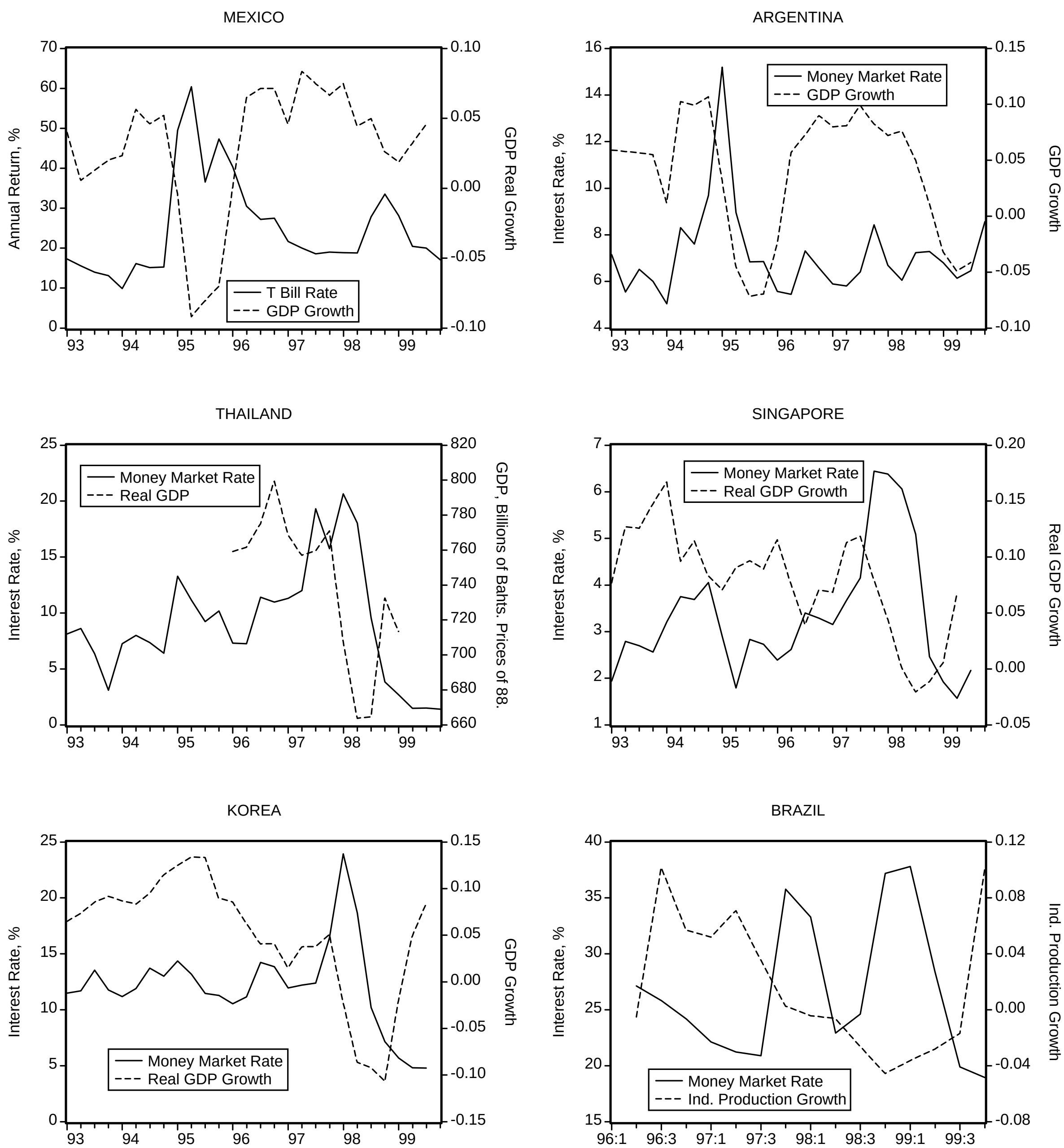

Figure 2. Timing of balance of payments crisis

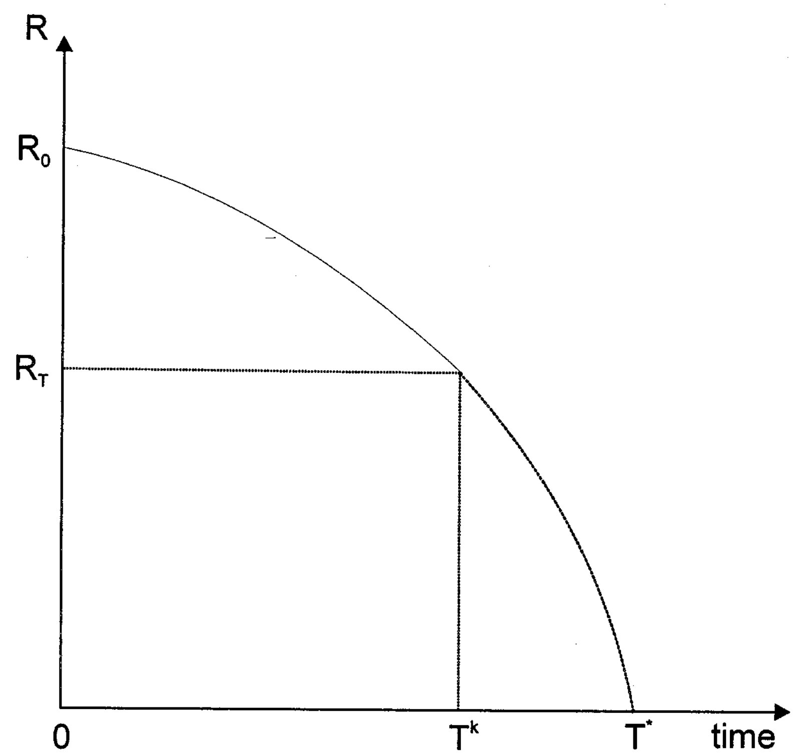

Figure 3. Contemporaneous interest rate defense

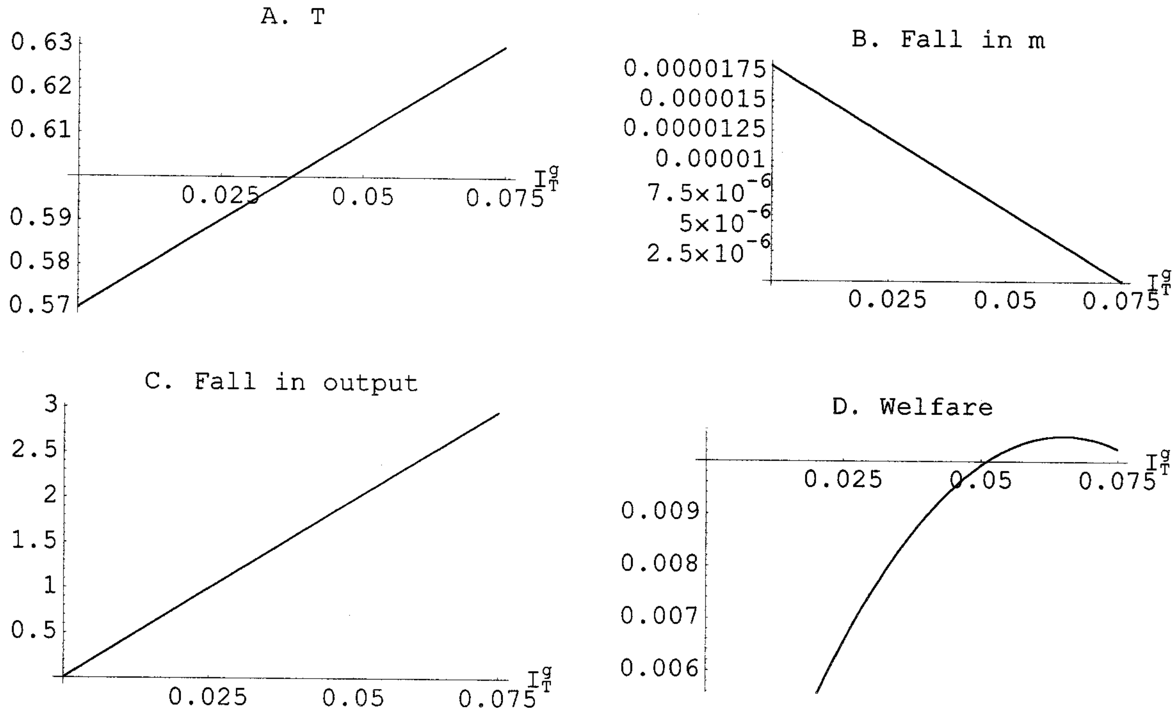

Figure 4. Preemptive interest rate defense

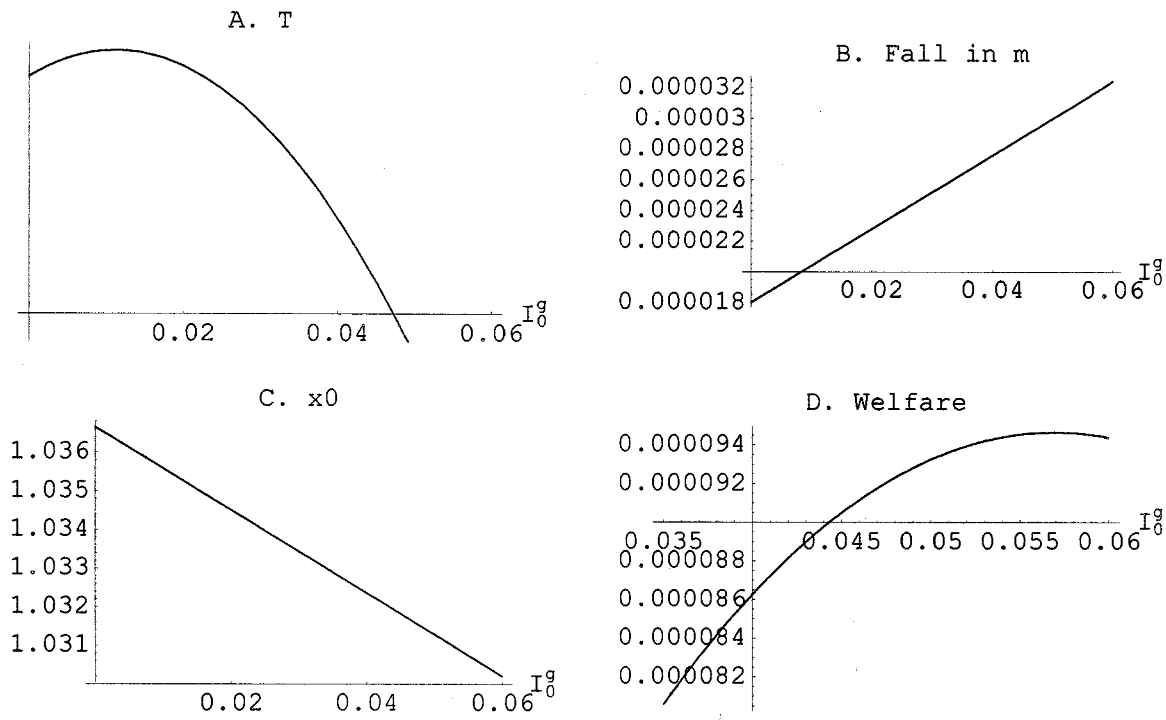

Figure 5. Optimal interest rate policy as a function of ϕ

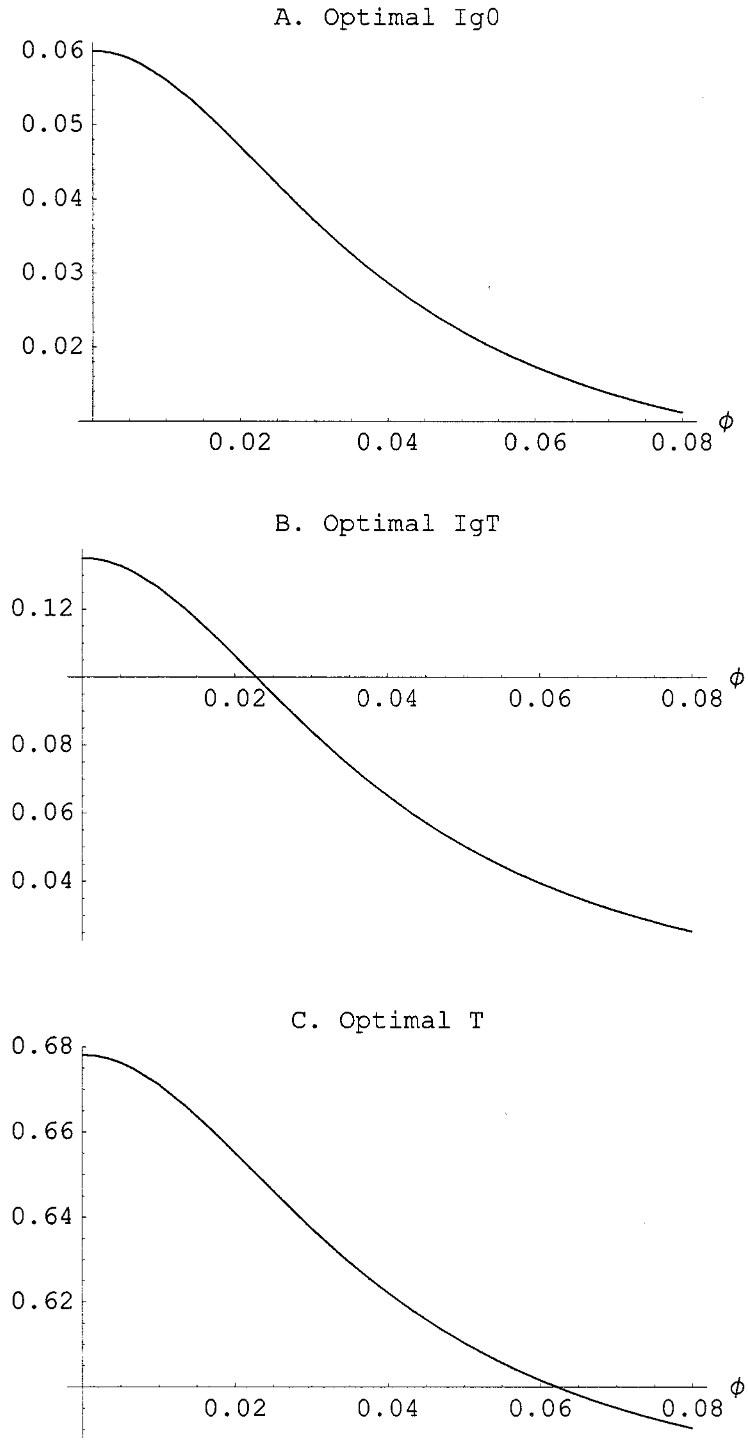

Figure 6. CES preferences: Optimal interest rate policy as a function of ϕ