

Fiscal imbalances and the dynamics of currency crises¹

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Abstract

This paper analyzes links between the fiscal theory of the price level (FTPL) and the first-generation models after Krugman (1979), exploring the idea that a synthesis between the two can become a new framework to analyze the fiscal dimension of currency crises. Working in a simple synthetic framework, we show how external nominal shocks can cause a fiscal imbalance and undermine currency stability, resolve two well-known paradoxes of the first generation model, discuss the role of seigniorage revenues, and illustrate how fiscal and interest rate policies interact to determine the magnitude and the timing of speculative attacks and devaluations.

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Key words and phrases: currency crisis, speculative attack, fiscal theory of the price level, public debt.

1 Introduction

In his macroeconomic lectures at Yale, Christopher Sims often remarked that the “first generation model” of currency crises due to Krugman (1979) and the fiscal theory of the price level (FTPL)¹ were “close cousins”. In this paper, we explore formally links between the FTPL and the Krugman model.² We specify a simple, tractable model that we see as a step toward a more general, synthetic model of fiscal imbalances and currency crises. Our analysis yields a number of new results and clarifies some aspects of the literature.

Although the Krugman model appeals informally to fiscal considerations, a currency crisis arises in that model exclusively as a consequence of domestic credit creation by the central bank. A strength of the Krugman model was its simplicity, but the model proved difficult to reconcile with evidence from recent currency crises. The observation that the currency crises in East Asia were not preceded by domestic credit expansion was a factor that motivated the first recent extension of the Krugman model. In Corsetti, Pesenti and Roubini (1999), a currency crisis is caused by *anticipated future* growth in domestic credit. Soon it became apparent that this extension *per se* would be insufficient to make the first generation model consistent with the recent crises. Burnside, Eichenbaum and Rebelo (2001, 2003a, 2003b), henceforth BER, documented that while the devaluations in Latin America, East Asia and Turkey were associated with large fiscal imbalances, governments financed only moderate fractions of the imbalances with seigniorage revenues. A decrease in the real value of nominal government liabilities played a quantitatively more important role than seigniorage revenues. In an effort to match the evidence BER extended the first generation model, including in it nominal government liabilities (such as domestic-currency debt and spending commitments not indexed to the exchange rate).

Daniel (1998, 2001a) applies more directly than BER two insights from the FTPL in a model of currency crises. Given a fiscal imbalance, the government budget constraint *seen as an equilibrium condition* implies that the price level increases and the exchange rate depreciates. The FTPL highlights the role of maturity of public debt in macroeconomic dynamics: long-term

¹E.g. Benhabib, Schmitt-Grohé and Uribe (2001), Leeper (1991), Sims (1994) and Woodford (1995).

²See Corsetti and Maćkowiak (2000) and Daniel (1998, 2001a).

nominal debt smooths out the effects of fiscal shocks on the equilibrium price level (Cochrane (2001) and Woodford (1998)). In Daniel's work long-term nominal debt helps delay devaluation, consistent with the FTPL.

The contributions of Corsetti, Pesenti and Roubini, BER and Daniel are sometimes seen as an alternative to the Krugman model. In light of Sims's remark, however, we see them as steps toward a new, synthetic model of fiscal imbalances and currency crises that will combine the insights of Krugman with those of the FTPL. In this paper, we take a further step towards building such a synthetic model.

Our starting point is the intuitive experiment of Krugman. We assume a fixed exchange rate and postulate an exogenous shock that decreases the present value of government's real primary surpluses relative to its outstanding liabilities. We then analyze the dynamics of adjustment. Different from the first generation model, we conduct our analysis in an economy with public debt of different denomination and maturity (domestic- and foreign-currency and short- and long-term). The key to the adjustment is that devaluation causes a wealth transfer from holders of nominal public liabilities that finances the fiscal imbalance. Unanticipated devaluation reduces the real value of short-term nominal debt; anticipated future devaluation creates a wealth transfer from holders of long-term nominal debt.

New results from our analysis can be summarized as follows:

(1) Shocks that cause a collapse of a fixed exchange rate can be *nominal*, and need not imply a deterioration of government's real primary surpluses. This is because nominal shocks affect the real value of debt and are thus capable *per se* of causing fiscal strain. Thus a foreign deflationary shock (e.g., in the case of a country pegging to the euro, an appreciation of the euro relative to the dollar) can jeopardize the sustainability of a currency peg independently of changes in relative goods prices or "competitiveness" problems.

Consider prospective entrants to the EMU, expected to keep their currencies stable *vis-à-vis* the euro prior to entry. Our model makes it clear that a stable path of real primary surpluses, and their sufficient reaction to external *real* shocks, will not be enough for the pegs to be viable. What is required in addition is the ability to adjust real primary surpluses in reaction to foreign *nominal* shocks.

(2) The literature explains the timing of a currency crisis *via* a lower bound on exchange reserves (which corresponds to an upper bound on public borrowing). We show that the timing is also uniquely pinned down by a policy rule specifying the behavior of the short-term nominal interest rate. We see this shift of emphasis as realistic, since policymakers view themselves nowadays primarily as setting the short-term nominal interest rate. Moreover, the new focus helps avoiding two well-known paradoxes of the first generation model: the currency *appreciates* in that model if the exchange rate parity is abandoned “too early”, despite the fiscal crisis, and there can be trade at *off-equilibrium* prices. Our specification with an interest rate rule avoids any such odd implications.

(3) The cause of a currency crisis is fiscal, with expansion of domestic credit and seigniorage revenues being a sideshow. To illustrate this most clearly, our model abstracts from base money. We thus show that a fiscal imbalance can cause an abandonment of a currency peg *independently* of any need for seigniorage revenues. If a currency crisis can be consistent with *zero* seigniorage revenues, it is *a fortiori* consistent with modest seigniorage gains seen in the recent episodes.

Abstracting from money does *not* mean that we cannot use the model to analyze the effects of policy rules that change the interest rate on short-term nominal government bonds. Interest rate rules constitute monetary policy in our model. In Corsetti and Maćkowiak (2000, 2003) we show that the model *with* money, introduced in a standard way, behaves in the same way and all our results go through. Here we omit money to make the model simpler, in effect deleting an equation that would mechanically define the quantity of base money demanded for a given short-term nominal interest rate.

The model clarifies what determines the size of a currency crisis. The magnitude of the crisis in the model is nonlinearly increasing in the fraction of public liabilities denominated in a foreign currency. The nonlinearity lets us understand why a government that borrows heavily in a foreign currency, like many emerging markets, is exposed to a devaluation of dramatic size.

Our model clarifies characteristics of the post-crisis steady state and, in particular, the relation between the magnitude of devaluation and the rate of inflation in the post-crisis steady state. The post-devaluation regime in the Krugman model exhibits chronic depreciation (inflation). Furthermore, the first generation model implies a positive relation between the size

of the currency crisis and the rate of chronic inflation. In contrast, in the recent episodes we witnessed one-time devaluations of large magnitude followed by little ongoing inflation. Our model predicts that a fiscal imbalance causes a one-time devaluation. Post-devaluation policy can set the nominal interest rate at *any* desired level, not necessarily switching to a regime of chronic depreciation. Furthermore, the relation between the magnitude of devaluation and the inflation rate in the post-devaluation steady state is *negative*.³ The reason is that higher long-run inflation implies a larger capital loss to holders of long-term nominal public debt. Thus a currency crisis of striking proportions is consistent with *zero* inflation in the post-collapse steady state.⁴

The rest of the paper is organized as follows. The following section 2 presents the model, discussing shocks that can cause a fiscal imbalance as well as the fiscal rule and the interest rate rule. Section 3 uses the model to analyze the dynamic adjustment to a fiscal imbalance, discussing in turn determinants of the equilibrium exchange rate, the timing of speculative attacks, and the resolution of the paradoxes of the first generation model. Section 4 concludes, completing the discussion of the relationship between our framework and the first generation literature. In an appendix, we describe the behavior of the model when post-devaluation interest rate policy is more general than a simple interest rate peg we consider in the main text.

³This property is blurred when it is assumed that the central bank abandons the fixed exchange rate when reserves hit a lower bound, and then expands the monetary base at a constant rate. The magnitude of devaluation is then increasing in the long-run inflation rate (see Daniel (2001a)). The BER model can predict an inverse relationship between the rate of “burst” depreciation at the onset of the crisis and the long-run depreciation rate, when one reinterprets the long-run depreciation rate as a policy choice variable in the BER model.

⁴In the first generation model, real money decreases in the post-devaluation regime. The reason is that a standard money market equilibrium relation makes the quantity of real money a negative function of the chronic depreciation rate. In the version of our model with money, money supply adjusts at the time of devaluation consistent with the interest rate policy, and there is no implication that real money decreases relative to the fixed exchange rate period (see Corsetti and Maćkowiak (2000)).

2 The model

This section lays out a simple fully-specified model to study the dynamic adjustment to a one-time, unanticipated fiscal imbalance in a fixed exchange rate regime. Consider a small open-economy, with a government and a representative individual who receives an endowment of a single, tradable and perishable consumption good. In the single-good world economy with costless trade, the domestic price level P and the foreign (foreign currency) price level P^* are linked by the law of one price: $P = \mathcal{E}P^*$, where \mathcal{E} denotes the exchange rate. The economy takes exogenously the foreign real interest rate (equal to the foreign currency nominal rate). We assume that the interest rate is equal to a constant r such that $(1+r)\beta = 1$, where β is the representative individual's discount factor.

2.1 The representative individual's optimum problem

The representative individual in the small economy holds single-period nominal bonds B paying the interest rate i , a single-period foreign currency bonds B^* paying the interest rate r , and long-term debt in the form of nominal perpetuities L selling at the price θ . We assume that B and L are each strictly greater than zero, issued by the government and held only by the representative individual, whereas foreign currency bonds can be traded internationally.⁵ We think of the price level, P , as the rate at which a newly issued, single-period nominal public bond trades for the real commodity. We think of the single-period nominal interest rate as the rate at which the government exchanges maturing bonds for new ones; and of the perpetuity as an asset promising one unit of short-term bonds in every period from now on.

The representative individual maximizes:

$$\sum_{t=0}^{\infty} \beta^t \ln C_t \tag{1}$$

subject to:

$$\frac{\theta_t L_t}{P_t} + \frac{B_t}{P_t} + \frac{\mathcal{E}_t B_t^*}{P_t} \leq \frac{(1+\theta_t) L_{t-1}}{P_t} + \frac{(1+i_{t-1}) B_{t-1}}{P_t} + \frac{\mathcal{E}_t (1+r) B_{t-1}^*}{P_t} + Y_t - \tau_t - C_t$$

⁵The distribution of nominal claims on the government between domestic agents and foreigners matters for a welfare evaluation of a crisis, something we leave for future research.

in every period, as well as to:

$$\lim_{t \rightarrow \infty} \left(\frac{1}{1+r} \right)^t \left(\frac{\theta_t L_t}{P_t} + \frac{B_t}{P_t} + \frac{\mathcal{E}_t B_t^*}{P_t} \right) \geq 0$$

where Y and C denote endowment and consumption of the single good, respectively, and τ are real lump-sum taxes (or transfers, if negative).⁶

The first order conditions with respect to B^* and B imply that uncovered interest rate parity holds:

$$1 + i_t = (1+r) \frac{\mathcal{E}_{t+1}}{\mathcal{E}_t} \quad (2)$$

and the first order condition with respect to L yields an intertemporal relationship between perpetuity prices:

$$\theta_t (1 + i_t) = 1 + \theta_{t+1} \quad (3)$$

Solving equation (3) forward, we arrive at a relationship between the perpetuity price and future nominal interest rates:⁷

$$\theta_t = \sum_{s=0}^{\infty} \left[\prod_{k=0}^s \left(\frac{1}{1+i_{t+k}} \right) \right] \quad (4)$$

The transversality condition of the agent's problem is:

$$\lim_{t \rightarrow \infty} \left(\frac{1}{1+r} \right)^t \left(\frac{\theta_t L_t}{P_t} + \frac{B_t}{P_t} + \frac{\mathcal{E}_t B_t^*}{P_t} \right) = 0 \quad (5)$$

2.2 The government budget constraint

The period-by-period consolidated government budget identity is:

$$\frac{\theta_t L_t}{P_t} + \frac{B_t}{P_t} + \frac{\mathcal{E}_t F_t}{P_t} = \frac{(1 + \theta_t) L_{t-1}}{P_t} + \frac{(1 + i_{t-1}) B_{t-1}}{P_t} + \frac{\mathcal{E}_t (1+r) F_{t-1}}{P_t} - \tau_t \quad (6)$$

⁶Our original motivation to assume the log specification of consumption was to downplay the role of seigniorage in a model with money (see Corsetti and Maćkowiak (2000)). In that early version of the paper, we assume money in the utility function, also entering in logs. The elasticity of money demand is then such that the government cannot collect any revenues from seigniorage. Daniel (2001a) also assumes that consumption and money enter utility in logs, but does not discuss (the absence of) the role for seigniorage in her model.

⁷We restrict attention to competitive equilibria in which the following terminal condition holds:

$$\lim_{s \rightarrow \infty} \left[\prod_{k=0}^s \left(\frac{1}{1+i_{t+k}} \right) \right] \theta_{t+s+1} = 0$$

where F denotes single-period foreign currency bonds issued by the government. Notice our assumption that the government can borrow in foreign currency at the world interest rate r , implying that it is not expected to default on its foreign currency bonds. Using the individual's first order conditions and the following terminal condition:

$$\lim_{t \rightarrow \infty} \left(\frac{1}{1+r} \right)^t \left(\frac{\theta_t L_t}{P_t} + \frac{B_t}{P_t} + \frac{\mathcal{E}_t F_t}{P_t} \right) = 0 \quad (7)$$

we obtain a solved-forward version of the government budget constraint (6):

$$\frac{(1 + \theta_t) L_{t-1} + (1 + i_{t-1}) B_{t-1}}{P_t} + \frac{\mathcal{E}_t (1 + r) F_{t-1}}{P_t} = \sum_{s=0}^{\infty} \left(\frac{1}{1+r} \right)^s \tau_{t+s} \quad (8)$$

In equilibrium, the real value of public liabilities equals the present discounted value of future real primary surpluses.

In a closed economy model, this derivation would simply make use of expression (5) as the terminal condition — we can see this by imagining a closed economy model with an identical setup except that B^* (or F) would denote indexed, or “real”, debt. An open-economy model like ours, however, introduces a problem: it is theoretically possible that, with perfect insurance markets between countries, debt of one government can grow without a bound — corresponding to an explosive growth of assets of another government. The private sector's transversality condition generates a terminal condition for solved-forward budget constraints of all governments taken together, rather than for the constraint of each government separately. Like Bergin (2000), Daniel (2001b) and Sims (1999), we find it realistic to consider equilibria that emerge when the government in an open economy faces a terminal condition in the form of expression (7).

To illustrate most clearly that seigniorage is an inessential part of the dynamics of a currency crisis in the presence of nominal public debt, the model abstracts from base money. In effect, we study devaluation scenarios in which none of the imbalance is financed by anticipated money growth, and all of it is financed by unanticipated wealth transfers from holders of nominal liabilities.⁸ The first generation model focuses on seigniorage as *the* adjustment mechanism to a fiscal imbalance. It is not evident that the role of seigniorage revenues in the adjustment

⁸Note that governments have many imperfectly indexed liabilities other than publicly traded bonds, including long-term spending commitments like pensions. Thus even a moderate change in the price level can bring about

to fiscal shocks is as important as the first generation literature suggests. We mention an empirically motivated objection in the introduction. At a theoretical level, one can write down a version of our model *with* money, introduced in a standard way, such that the present value of seigniorage is independent of the path of nominal interest rates (Corsetti and Maćkowiak (2000, 2003)). In this case, if the government delays devaluation, the present value of extra seigniorage revenues is zero. Thus anticipated money growth fails to produce any fiscal gains, and the model behaves exactly like the one in this paper.⁹

2.3 Equilibrium

A competitive equilibrium in this small open-economy is a specification for a time path of the vector $\{Y, r, C, B^*, B, L, F, \tau, i, \theta, \mathcal{E}, P^*, P\}$ such that: (I) when the representative individual takes the $\{Y, r, \tau, i, \theta, \mathcal{E}, P^*, P\}$ part of the path as given, $\{C, B^*, B, L\}$ solves her optimum problem; (II) the solved-forward government budget constraint (8) holds.¹⁰

2.4 Policy rules and shocks causing a fiscal imbalance

Suppose that the foreign price level is equal to a constant, P_α^* , and that the government fixes the exchange rate at $\bar{\mathcal{E}}$. For a fixed exchange rate to be sustainable, fiscal policy must be consistent with the government's solved-forward budget constraint (8) holding at $\bar{\mathcal{E}}$. Let $\{\bar{\tau}_{t+s}\}_{s=0}^{s=\infty}$ be a path of primary surpluses such that (8) holds given P_α^* and initial debt $(B_{t-1}, L_{t-1}$ and $F_{t-1})$ with the exchange rate *permanently* fixed at $\bar{\mathcal{E}}$, that is $\mathcal{E}_{t+s} = \bar{\mathcal{E}}$, $s \geq 0$. By definition, then, $\{\bar{\tau}_{t+s}\}_{s=0}^{s=\infty}$ is a sequence such that:

$$\sum_{s=0}^{\infty} \left(\frac{1}{1+r} \right)^s \bar{\tau}_{t+s} = \frac{(1+1/r)L_{t-1} + (1+r)B_{t-1}}{\bar{\mathcal{E}}P_\alpha^*} + \frac{(1+r)F_{t-1}}{P_\alpha^*} \quad (9)$$

substantial wealth transfers that help resolve a fiscal crisis. Simulations on the fiscal impact of moderate inflation in Sweden by Persson, Persson and Svensson (1998) provide an instructive example. Consistent with that study, one should interpret “nominal public debt” in our model in a broad sense.

⁹What matters for this result is the interest elasticity of money demand: depending on its value, it is even possible for net seigniorage revenues to be negative — adding to, rather than offsetting the fiscal imbalance. Lahiri and Vegh (1998) study in greater detail how the present value of seigniorage depends in the first generation model on the interest elasticity of money demand.

¹⁰ F , determined by government supply, need not equal B^* .

To satisfy the above condition, a sequence of τ 's must eventually imply a strong feedback from debt to τ 's. In response to shocks hitting the economy, policy must set a path of τ 's so as to insure that primary surpluses fully back debt, given $\bar{\mathcal{E}}$. The FTPL literature refers to this fiscal policy as *passive* or *Ricardian*.

Recent contributions begin, in the spirit of Krugman, by assuming that the government fails to stick to a Ricardian policy. The motivation of e.g. Corsetti, Pesenti and Roubini (1999) and Burnside, Eichenbaum and Rebelo (2001) is the arrival of news about a bailout of private companies. As a complement to focusing directly on a deterioration of primary surpluses, it is appealing to motivate a fiscal imbalance as a consequence of an external shock.¹¹ Most economists would probably find it intuitive that a change in real international prices exogenous to a small economy, like the terms-of-trade or the world real interest rate, can result in fiscal slippage. What is not readily apparent, and what this model makes clear, is that a foreign *nominal* shock can also lead to a fiscal imbalance with critical consequences for a fixed exchange rate policy.

Suppose the foreign price level changes in period t to a new, permanent level P_β^* where $P_\beta^* \leq P_\alpha^*$. Provided the inequality is strict, the shock increases on impact the real value of both nominal and foreign currency debt. Foreign deflation increases the quantity of the real commodity the government promises to bondholders, regardless of whether their claims are denominated in domestic or in foreign currency. Given the definition of $\{\bar{\tau}_{t+s}\}_{s=0}^{s=\infty}$, we now write the solved-forward government budget constraint (8) in period t as follows:

$$\frac{(1 + \theta_t) L_{t-1} + (1 + r) B_{t-1}}{\mathcal{E}_t P_\beta^*} + \frac{(1 + r) F_{t-1}}{P_\beta^*} = \left[\sum_{s=0}^{\infty} \left(\frac{1}{1 + r} \right)^s \bar{\tau}_{t+s} \right] - \Delta \quad (10)$$

where \mathcal{E}_t may or may not equal $\bar{\mathcal{E}}$ in equilibrium. In the above expression, Δ is a measure of the extent of fiscal adjustment the government undertakes in reaction to the shock, with $\Delta < 0$ corresponding to improvement and $\Delta > 0$ to deterioration beyond the immediate effect of the

¹¹There is a vector-autoregressive literature documenting that a substantial fraction of macroeconomic variation in small economies originates abroad (e.g. Calvo, Leiderman and Reinhart (1993), Canova (2003), Cushman and Zha (1997) and Maćkowiak (2003)).

shock.¹² A restriction we place on Δ is that it satisfies:

$$\Delta > \left[\sum_{s=0}^{\infty} \left(\frac{1}{1+r} \right)^s \bar{\tau}_{t+s} \right] - \left[\frac{(1+1/r)L_{t-1} + (1+r)B_{t-1}}{\bar{\mathcal{E}}P_{\beta}^*} + \frac{(1+r)F_{t-1}}{P_{\beta}^*} \right]$$

Thus we in effect assume that the shock coincides with fiscal policy becoming *active* or *non-Ricardian*, in the terminology of the FTPL literature.

The fiscal implications of nominal shocks have not been noted by previous contributions on speculative attacks. Yet two realistic scenarios make the case $P_{\beta}^* < P_{\alpha}^*$ interesting. The first is deflation, or a fall in the inflation rate, in the United States (think of dollar pegs) or in the euro area (think of prospective entrants to the EMU, expected to keep their currencies stable *vis-à-vis* the euro prior to entry). Our model makes it clear that a stable path of real primary surpluses, or their sufficient reaction to external real shocks, will not be enough for the pegs to be viable. What is required in addition is the ability to adjust real primary surpluses in reaction to foreign *nominal* shocks. Second, we are motivated by the role of Brazil's devaluation in 1999 in the recent crisis in Argentina. A devaluation in Brazil decreases international prices faced by Argentina. While this is an improvement in Argentina's terms-of-trade or a relative price change, the impact of the shock on the real value of Argentina's public debt is equivalent to that of a decrease in P^* or a purely nominal shock.¹³

While we think of the case $P_{\beta}^* < P_{\alpha}^*$ as a realistic example, our analysis allows for the possibility that $P_{\beta}^* = P_{\alpha}^*$ because we do not want to specialize to only one source of a fiscal imbalance. An adverse shock underlying Δ can stem from a variety of external and domestic sources. Once this disturbance occurs, the government may attempt to adjust the path of its budgets in an effort to reverse the negative impact of the shock. What we assume is that the government cannot (or is not willing to) introduce spending or tax adjustments such that its

¹²For example, one can assume that from time T_d onwards primary surpluses change by a constant d :

$$\Delta \equiv \frac{(1+r)d}{r} \left(\frac{1}{1+r} \right)^{T_d-t}$$

Letting $T_d \geq t$ allows for the possibility that primary surpluses change at a future date.

¹³A model with a nominal rigidity might predict a decrease in Argentina's output in reaction to Brazil's devaluation, and thus a deterioration in Argentina's real primary surpluses. See e.g. Hausmann and Velasco (2002) for an analysis of the crisis in Argentina, including a discussion of the impact of Brazil's devaluation on its neighbor.

debt continues to be backed fully with real taxes, and equation (8) holds with the exchange rate permanently fixed at $\bar{\mathcal{E}}$. Thus Δ is defined as the net change in the present value of real primary surpluses *after* the government has taken all measures it deemed feasible to reverse the impact of the shock. Note that the restriction on Δ implies that $\Delta > 0$ so long as $P_\beta^* = P_\alpha^*$.

Having described fiscal policy, we complete the model by specifying an interest rate rule. So long as the exchange rate is fixed at $\bar{\mathcal{E}}$, the nominal interest rate is determined by uncovered interest rate parity (2) evaluated at $\mathcal{E}_t = \bar{\mathcal{E}}$. In the event of a devaluation, we assume that the interest rate is set according to the reaction function:

$$1 + i_{\tilde{T}+s} = \phi_0 + \phi_1 \frac{\mathcal{E}_{\tilde{T}+s}}{\mathcal{E}_{\tilde{T}+s-1}} \quad (11)$$

where $\tilde{T} \geq t$ is the period of devaluation, and $s \geq 0$. According to this rule, the (gross) nominal interest rate is a linear function of the (gross) depreciation rate. We assume that $\beta\phi_1 < 1$, i.e. policy makes i react weakly to depreciation (or inflation) — this is an instance of *passive* interest rate policy familiar from the FTPL literature. Note that the reaction function (11) is consistent e.g. with inflation targeting in the post-devaluation period.¹⁴ To derive closed-form solutions, in the main text we specialize to a simple interest rate peg such that $i_{\tilde{T}+s} = i^p$ (that is, $\phi_1 = 0$ and $\phi_0 - 1 = i^p$), $s \geq 0$, and examine the general rule (11) in an appendix. Note that the choice of i^p determines the rate of chronic depreciation in the post-devaluation period.

3 Adjustment to a fiscal imbalance

We now use our framework to analyze the adjustment to a given fiscal imbalance, a classic topic since Krugman’s work. To build intuition and to facilitate comparison with Cochrane (2001), Daniel (2001a) and Woodford (1998), we initially focus on the case in which the government abandons the peg in the same period when a fiscal imbalance appears — thus causing an unanticipated jump in the exchange rate at t . We then consider the case in which the parity is abandoned at some later date $\tilde{T} > t$.

¹⁴We also assume that $\beta\phi_0 \geq 1 - \beta\phi_1$ so that the post-devaluation (gross) chronic depreciation rate converges to a number greater than or equal to 1. This assumption is inessential for substantive results of this paper, but allows us to rule out persistent deflation after devaluation.

3.1 Devaluation with foreign nominal shocks and shocks to primary surpluses

An immediate, unanticipated devaluation in period t reduces the real value of B and L , resulting in a wealth transfer, while the post-devaluation interest rate rule determines θ_t . A higher rate of chronic post-devaluation inflation reduces θ_t — by equation (4) — creating an additional wealth transfer. In equilibrium, the wealth transfers due to jumps in the exchange rate and the price of perpetuities finance the fiscal imbalance. Formally, once policy chooses the post-collapse nominal interest rate $i_{t+s} = i^p$, $s \geq 0$, the equilibrium condition (4) yields the perpetuity price $\theta_t = (1/i^p)$. To solve for the equilibrium devaluation rate $(\mathcal{E}_t/\bar{\mathcal{E}})$, we make use of the solved-forward government budget constraint — combining equations (9) with (10). Let π_t^* denote unexpected foreign inflation at time t : $\pi_t^* \equiv \frac{P_\beta^* - P_\alpha^*}{P_\alpha^*}$; note that $\pi_t^* \leq 0$. Let \mathcal{B}_{t-1} denote the initial stock of short-term debt in domestic currency (and \mathcal{F}_{t-1} — the stock of debt in foreign currency), expressed as ratios of long-term debt:

$$\begin{aligned}\mathcal{B}_{t-1} &\equiv \frac{(1+r)B_{t-1}}{L_{t-1}} \\ \mathcal{F}_{t-1} &\equiv \frac{(1+r)\bar{\mathcal{E}}F_{t-1}}{L_{t-1}}\end{aligned}$$

Finally, define ℓ_{t-1} as the real value of long-term debt conditional on no devaluation, i.e. $\ell_{t-1} \equiv \frac{L_{t-1}}{\bar{\mathcal{E}}(1+\pi_t^*)P_\alpha^*}$. We can write the unique solution for the equilibrium devaluation rate as follows:

$$\frac{\mathcal{E}_t}{\bar{\mathcal{E}}} = \frac{\frac{1+i^p}{i^p} + \mathcal{B}_{t-1}}{\frac{(1+\pi_t^*)(1+r)}{r} + (1+\pi_t^*)\mathcal{B}_{t-1} + \pi_t^*\mathcal{F}_{t-1} - \frac{\Delta}{\ell_{t-1}}}\tag{12}$$

Equation (12) highlights several properties of the equilibrium devaluation rate $(\mathcal{E}_t/\bar{\mathcal{E}})$: (i) The jump in the exchange rate is increasing in the size of the fiscal imbalance: $(\mathcal{E}_t/\bar{\mathcal{E}})$ is decreasing in π_t^* (P_β^*) and increasing in Δ . The exchange rate change is determined both by the size of the shock and by the policy reaction to it. (ii) For any given imbalance, foreign currency debt acts as leverage — the higher the fraction of debt denominated in foreign currency, the larger the devaluation rate. An economy in which the government borrows heavily in foreign currency, like many emerging markets, sees a larger jump in the exchange rate for a given fiscal

imbalance. The leverage property of foreign-currency debt is most easily seen by inspecting (10) or — in equation (12) — by considering an increase in \mathcal{F}_{t-1} with an unchanged \mathcal{B}_{t-1} so that ℓ_{t-1} decreases. (iii) Post-devaluation interest rate policy influences $(\mathcal{E}_t/\bar{\mathcal{E}})$, because the post-collapse path of interest rates determines the long-term bond price. Specifically, a higher i^p implies a larger jump in θ_t , and consequently a smaller one-time devaluation rate $(\mathcal{E}_t/\bar{\mathcal{E}})$. Thus a currency crisis followed by little long-run inflation, like in some recent episodes, is associated with a larger initial exchange rate adjustment. In fact, setting $i^p = r$ implies that the depreciation rate in the post-devaluation steady state is zero. If no further shocks hit the economy, the dynamics involve a (relatively larger) one-time jump in the exchange rate to a new, constant level.¹⁵

It is straightforward to check that the unique solution to the solved-forward government budget constraint satisfies the other equilibrium conditions, and therefore is the unique equilibrium exchange rate. In particular, given i^p and \mathcal{E}_t , uncovered interest rate parity (2) determines the rate of depreciation $(\mathcal{E}_{t+1}/\mathcal{E}_t)$. The result that non-Ricardian fiscal policy and passive interest rate policy deliver a uniquely determinate price level and a stationary inflation rate is familiar from the FTPL literature.¹⁶

3.2 Determinants of the rate of devaluation and the “shadow exchange rate”

Expression (12) gives the equilibrium exchange rate conditional on devaluation at time t . After Flood and Garber (1984), economists refer to equilibrium exchange rate conditional on abandoning the peg as *shadow exchange rate*.¹⁷ This section characterizes the shadow rate (analogous to expression (12)), if the peg is *not* abandoned at the time when the fiscal imbalance materializes.

Can the government choose to delay devaluation until some period $\tilde{T} > t$? For a delay to be consistent with equilibrium, the solved-forward government budget constraint must hold with $\mathcal{E}_t = \bar{\mathcal{E}}$ exclusively by virtue of a wealth transfer from holders of nominal *long-term* debt,

¹⁵We assume that i^p is chosen so that $\mathcal{E}_t > \bar{\mathcal{E}}$.

¹⁶To determine the equilibrium level of consumption, so long as $P_\beta^* < P_\alpha^*$, we would need to make an arbitrary assumption regarding the small economy’s net international asset position in foreign currency bonds.

¹⁷See Cavallari and Corsetti (2000) for a generalization of the concept to first- and second-generation models.

due to an unanticipated jump in θ_t . Thus a delay is consistent with equilibrium only if L is of sufficient size relative to the imbalance; otherwise, the exchange rate must jump immediately in equilibrium. While the model considers perpetuities for simplicity, the point is general: abstracting from seigniorage, the government can postpone devaluation only if it has a large enough stock of nominal debt of sufficient maturity. This is a condition emerging markets are less likely to satisfy than developed economies. It is noteworthy that the maturity of public debt is key to delayed adjustment also in a model allowing for deviations from the law of one price.¹⁸

Assuming that this condition holds in our economy, we combine equations (9) and (10) with $\mathcal{E}_t = \bar{\mathcal{E}}$ to solve for the equilibrium perpetuity price in period t :

$$\theta_t = (1 + \pi_t^*) \left(\frac{1}{r} - \Delta \frac{\bar{\mathcal{E}} P_\alpha^*}{L_{t-1}} \right) + \pi_t^* (\mathcal{B}_{t-1} + \mathcal{F}_{t-1}) > 0. \quad (13)$$

θ_t is uniquely defined, because the jump in the bond price must guarantee that the solved-forward government budget constraint holds with $\mathcal{E}_t = \bar{\mathcal{E}}$. Note that a larger stock of long-term debt in domestic currency, L_{t-1} , acts as a cushion to the government, being associated with a smaller jump in the bond price. Letting $\tilde{T} > t$ denote the date at which the government abandons the peg, we use (2) and (3) as well as the policy rule $i_{\tilde{T}+s} = i^p$, $s \geq 0$ to obtain an

¹⁸The adjustment to a fiscal imbalance depends on the size and on the maturity of debt denominated in domestic currency. An important question is whether this conclusion is robust to deviations from the law of one price. In Corsetti and Maćkowiak (2003), we address this issue by extending our framework to include a nontraded good. We investigate whether there is an equilibrium in which, when a fiscal imbalance appears, the price of nontradables rises in such a way that the resulting decrease in the real value of nominal public debt finances the imbalance. If such an equilibrium existed, the government could choose to postpone devaluation without any long-term liabilities outstanding (and without having recourse to seigniorage revenues). The adjustment mechanism would involve a real appreciation in anticipation of a speculative attack: *price level* inflation would bring about a fiscal transfer consistent with temporary *exchange rate* stability. We find that such an equilibrium fails to exist. Thus the introduction of nontraded goods *per se* fails to overturn this paper's result: without long-term debt, the equilibrium must involve an immediate devaluation. In an economy with multiple goods, debt maturity remains critical for understanding when a given fiscal shock affects the equilibrium exchange rate. The details are in Corsetti and Maćkowiak (2003).

intertemporal relationship between perpetuity prices in periods t and \tilde{T} :

$$\theta_t = \frac{1}{r} + \left(\frac{1}{1+r} \right)^{\tilde{T}-t-1} \left(\frac{1 + (1/i^p)}{(1+r) \left(\mathcal{E}_{\tilde{T}}/\bar{\mathcal{E}} \right)} - \frac{1}{r} \right) \quad (14)$$

Putting together equations (13) and (14) yields the unique solution for the shadow exchange rate, i.e. the equilibrium exchange rate $\mathcal{E}_{\tilde{T}}$ conditional on devaluation in period $\tilde{T} > t$:¹⁹

$$\frac{\mathcal{E}_{\tilde{T}}}{\bar{\mathcal{E}}} = \frac{\frac{1 + i^p}{i^p}}{\frac{1+r}{r} - (1+r)^{\tilde{T}-t} \left[\frac{\Delta}{\ell_{t-1}} - \pi_t^* (1 + \mathcal{B}_{t-1} + \mathcal{F}_{t-1}) \right]} \quad (15)$$

The equality confirms that the shadow exchange rate retains the properties of equation (12): (i) A larger imbalance Δ and a smaller π_t^* (P_β^*) require a greater jump in the bond price and a larger devaluation rate at any date. (ii) An increase in post-devaluation interest rates (or in long-run inflation) decreases the devaluation rate. (iii) Domestic-currency debt acts to decrease the government's leverage, being associated with a smaller devaluation rate. This last property becomes most transparent when abstracting from foreign inflation, i.e., by considering the role of L_{t-1} in expression (15) in the limiting case $\pi^* \rightarrow 0$:

$$\frac{\mathcal{E}_{\tilde{T}}}{\bar{\mathcal{E}}} = \frac{\frac{1 + i^p}{i^p}}{\frac{1+r}{r} - (1+r)^{\tilde{T}-t} \Delta \frac{\bar{\mathcal{E}} P_\alpha^*}{L_{t-1}}} \quad (16)$$

In addition to what was apparent from equation (12), we now see from (15) that delaying the collapse further into the future (i.e. an increase in \tilde{T}) raises the equilibrium devaluation rate.²⁰

A back-of-the-envelope calculation using the shadow devaluation rate sheds light on the properties of the model, and on its potential empirical relevance. A relatively small change in the extent of “dollarization” can lead to large differences in the magnitude of a crisis. Assume for instance that public debt is 50% of GDP. Then the impact of a combination of 10% of

¹⁹Expressions similar to (12) and (15) are the core of the contribution by Daniel (1998, 2001a), whereas there is no foreign inflation and monetary policy is specified in terms of money growth. Daniel's interpretation is that monetary policy can choose (subject to equilibrium behavior of private agents) two of the three variables: the magnitude of devaluation, the timing of devaluation and the post-collapse steady-state inflation rate.

²⁰Following our discussion of devaluation in period t , it should be evident that the unique solution for $(\mathcal{E}_{\tilde{T}}/\bar{\mathcal{E}})$ satisfies the other equilibrium conditions.

foreign deflation and a fiscal imbalance of $\Delta = 0.1$ (10% of GDP, in present value) more than doubles when the share of foreign currency debt increases from 80 to 90%. These numbers are realistic since, for example, Levy (2002) reports for Argentina a share of foreign currency bonds in public debt of 87-98% between 1997 and 2001.

3.3 The timing of speculative attacks: analogies and differences with the first generation model

Our framework shares the basic feature of the first generation model: the emergence of a fiscal imbalance implies that the currency depreciates in finite time. To see this, note that, when calculating $(\mathcal{E}_{\hat{T}}/\bar{\mathcal{E}})$, we have assumed that the fiscal imbalance Δ is no larger than the present value of the maximum wealth transfer from long-term bond holders:

$$\frac{1+r}{r} > (1+r)^{\hat{T}-t} \left[\frac{\Delta}{\ell_{t-1}} - \pi_t^* (1 + \mathcal{B}_{t-1} + \mathcal{F}_{t-1}) \right] \quad (17)$$

The above formula suggests that a currency collapse must occur before the passage of time changes the sign of the above inequality, i.e. before \hat{T} such that:

$$\hat{T} \simeq t + \frac{r - \log r}{r} - \frac{1}{r} \log \left[\frac{\Delta}{\ell_{t-1}} - \pi_t^* (1 + \mathcal{B}_{t-1} + \mathcal{F}_{t-1}) \right] \quad (18)$$

Focusing on the case $\pi_t^* \rightarrow 0$ makes the logic of the above expression even more transparent:

$$\hat{T} \simeq t + \frac{r - \log r}{r} - \frac{1}{r} \log \Delta + \frac{1}{r} \log \left(\frac{L_{t-1}}{\bar{\mathcal{E}} P_\alpha^*} \right)$$

The larger is the stock of long-term nominal debt L_{t-1} , the longer can the government keep the exchange rate fixed.

Conditional on Δ , π_t^* and on initial stock of debt, there exists a finite upper bound \hat{T} to the date of devaluation, given by expression (18). Note the implication that the government can borrow to defend the peg until \hat{T} . Following Grilli (1986), we refer to \hat{T} as the time of a *natural collapse* of the exchange rate. In more general specifications, the natural collapse date will depend on utility and technological parameters as well as on *seigniorage* (perhaps most important from the viewpoint of the first generation literature), but will remain finite. An increase in the present value of seigniorage will give the government more resources to

back its debt, decreasing the shadow exchange rate much like an increase in i^p in this model (Maćkowiak (2002)).²¹

While a fiscal imbalance makes devaluation inevitable, the model fails to pin down the date of the collapse — any period between t and \hat{T} can be the devaluation date. This is an important difference relative to the first generation model, with its uniquely defined date of a speculative attack. One might be tempted to close our model by assuming that the timing of the crisis is determined by the currency and maturity composition of public debt — i.e. that the currency collapses at a date close to \hat{T} . The problem with such an approach is that a collapse at \hat{T} corresponds to an extreme scenario in which the government extracts close to the maximum wealth transfer: evaluating expression (15) as $\tilde{T} \rightarrow \hat{T}$, we find that such a crisis is associated with near-infinite, unrealistic rates of devaluation.

Alternatively, one might be tempted to refine the new framework in the spirit of Flood and Garber, by positing that a crisis occurs in the first period in which the shadow exchange rate (uniquely defined in every period between t and \hat{T}) is above $\bar{\mathcal{E}}$. However, the Flood and Garber rule does not work in the new framework. First, such a rule cannot be derived as an equilibrium condition like in the first generation models. Second, unless i^p is high and the fiscal imbalance is small, the shadow exchange rate jumps above $\bar{\mathcal{E}}$ *already in period t* , remaining above it at all subsequent dates. Adopting the Flood and Garber rule would make the model predict an immediate collapse at t for most values of parameters.

3.4 Interest rate policy and the dynamics of currency crises

A lesson from the first generation model is that the timing of a speculative attack may be determined by a constraint on the central bank. We follow this modeling tradition, but switch the focus from international reserves to interest rate rules. Our motivation is twofold: (1) the

²¹If the government attempted to delay the devaluation past \hat{T} , its solved-forward budget constraint would fail to hold with $\mathcal{E}_t = \bar{\mathcal{E}}$, and the peg would collapse in period t . Lahiri and Vegh (2003) introduce a government bond that is assumed to have utility value. Therefore the price of the bond is not determined exclusively by uncovered interest parity. The government can borrow by issuing such bonds at increasing interest rates. Buiter (1987) assumes an upward-sloping supply schedule for reserves. Such considerations do not matter for the substance of our argument — they merely act to decrease \hat{T} as borrowing increases.

emphasis of recent macroeconomic literature and policy analysis on setting interest rates; (2) the fact that, enriched by an interest rate rule, our framework can avoid two paradoxes of the first generation model, as classic as the model itself.

Our starting point is the consideration that governments find high interest rates costly to implement. Specifically, we assume that there is a unique upper bound on the interest rate that policy is unwilling to cross: the government abandons the peg in the first period $\tilde{T} > t$ such that keeping the exchange rate fixed would cause the interest rate to rise to or above \bar{i} at \tilde{T} . The period $\tilde{T} - 1$ is then the last period in which the interest rate is below the policy-specified threshold:

$$\tilde{T} = \min s \quad \text{such that} \quad i_s \geq \bar{i} \quad (19)$$

The shadow exchange rate given in expression (15) maps one-to-one, by virtue of equation (2), into the *shadow nominal interest rate*, defined as the short-term nominal interest rate conditional on devaluation one period ahead. When policy delays devaluation, the shadow interest rate rises monotonically. Given an upper limit on the interest rate, the timing of a delayed devaluation is therefore *unique* within the interval between t and \hat{T} . Thus the model predicts that fiscal policy makes devaluation inevitable, but that its date is determined by interest rate policy. Other things equal, policymakers willing to let the interest rate rise higher can defend the peg longer.²²

The dynamics of adjustment given a fiscal imbalance are best captured by using the shadow exchange rate (see Figure 1) and the shadow interest rate (see Figure 2). The figures are drawn using equations (2) and (16) setting $i^p = r$. When the adverse news arrives at t , the shadow exchange rate jumps discontinuously,²³ then depreciates smoothly until period \tilde{T} , when it coincides with the actual exchange rate $\mathcal{E}_{\tilde{T}}$. The shadow interest rate also jumps at t , but remains below \bar{i} at $\tilde{T} - 1$. \tilde{T} is the first period in which the shadow interest rate is equal

²²Since the model includes short-term foreign currency debt, our economy may be subject to speculative attacks triggered by “sudden stops” à la Calvo (2003). Corsetti and Maćkowiak (2000) provide an example where the timing of the crisis is determined by a “sudden stop”.

²³The shadow exchange rate can depreciate or appreciate on impact. The latter case is possible when policy chooses a large i^p , generating a capital loss to holders of perpetuities that is more than enough to finance the imbalance at the time of the shock.

to or above \bar{i} . The realized interest rate equals its shadow value in period $\tilde{T} - 1$, when the “speculative attack” leading to the exchange rate crisis occurs.

Recall that in the first generation model the exchange rate realized in equilibrium continues to be equal to the shadow exchange rate in all periods after devaluation. In our model, as Figures 1 and 2 illustrate, the exchange rate realized in equilibrium is equal to the shadow exchange rate only in the period of devaluation, \tilde{T} . Likewise, the short-term nominal interest rate realized in equilibrium is equal to the shadow interest rate only in period $\tilde{T} - 1$. Recall from expression (15) that the shadow exchange rate is defined in our model as the equilibrium rate conditional on devaluation in a specific period. Since waiting before devaluing exacerbates the fiscal problem, delay requires a larger exchange rate and interest rate adjustment. But once the adjustment in the level of prices and the exchange rate takes place, the equilibrium interest rate at \tilde{T} and in all subsequent periods (and the equilibrium exchange rate at $\tilde{T} + 1$ and in all subsequent periods) are determined by post-devaluation interest rate policy. In Figures 1 and 2, the post-devaluation interest rate policy is assumed to set $i^p = r$.

The above specification avoids two long-standing paradoxes — issues we have always found awkward in the first generation model. As regards the first paradox, the first generation model contains a famous result, replicated in textbooks: the timing of a speculative attack is unique because, if agents attacked the peg “too early”, the currency would *appreciate*. What is awkward is that — if the central bank abandons the peg before being forced to do so by a speculative attack — the first generation model predicts an *appreciation*, even though everybody knows the fiscal problem. The predictions of our model appear to us more convincing: the shadow rate changes discontinuously at the time when the fiscal shock arrives and continues to depreciate smoothly thereafter. Once the jump up in the actual exchange rate is realized, there is no implication that it would have been a jump *down* an instant before.

The second paradox becomes apparent in discrete-time versions of the Krugman model. The assumption that the peg is abandoned when reserves hit an exogenous lower bound implies that there are two speculative attacks. One occurs at time $\tilde{T} - 1$, in anticipation of the currency collapse at \tilde{T} . Because of this attack, reserves are “lost”. The final decisive attack occurs in period \tilde{T} , when reserves are “exhausted”. What is awkward in this setup is that the exchange

rate at \tilde{T} is equal to the *post*-devaluation equilibrium value $\mathcal{E}_{\tilde{T}}$. Yet agents in the first generation model are able to trade in period \tilde{T} at an off-equilibrium price $\bar{\mathcal{E}}$. (The equilibrium value at \tilde{T} will not generally coincide with the old parity.) As Obstfeld (1986) points out, agents who buy reserves from the central bank implicitly receive a fiscal transfer at the time of the speculative attack. Our specification with an interest rate threshold avoids trade at an off-equilibrium price.²⁴

4 Conclusions

This paper presents a simple framework to analyze the fiscal dimension of a currency crisis. An advantage of our framework is that it allows a discussion of the role of public debt and interest rate rules, two topics at the center of policy discussions following the recent crises. We have shown how external nominal shocks can produce a fiscal imbalance and undermine currency stability, resolved two well-known paradoxes of the first generation model, discussed the role of seigniorage revenues, and illustrated how fiscal and interest rate policies interact to determine the magnitude and the timing of speculative attacks and devaluations.

Let us complete the discussion of the relationship between our framework and the first generation literature. The first generation authors emphasize the unique timing of devaluations caused by a fiscal imbalance — indeed, one often refers to uniqueness as one of the main insights from that literature. We note that according to the logic of the FTPL an imbalance *per se* implies only an upper bound for the timing. What explains this difference? The unique timing in the first generation models is due to an assumption of a minimum level of reserves — models with debt in effect assume that investors impose an exogenous borrowing constraint on the government. A different modeling strategy, an exogenous interest rate threshold, delivers the uniqueness result in our framework. It is apparent that the exogenous limit on reserves in the

²⁴Note that in a version of our model with money (see Corsetti and Maćkowiak (2000)), in period $\tilde{T} - 1$ there is a contraction in money demand in addition to the jump in the interest rate that we focus on here. There is no second speculative attack in period \tilde{T} and no exchange of reserves takes place at an off-equilibrium price. Next, suppose that one modified the Krugman model, by specifying that the central bank abandons the peg in the first period in which reserves would not be sufficient to withstand a speculative attack. This reformulation would resolve the second paradox, but not the first.

Krugman model is a special case of the constraint on interest rate policy we use. If one abstracts from the possibility of government borrowing — as Krugman does — his assumptions of an exogenous rate of domestic credit expansion and a lower threshold on reserves imply, taken together, a lower bound on the monetary base, or an upper limit on the interest rate.

This paper points to a number of questions for further research. First, we have seen that small changes in the extent of “dollarization” can cause large differences in the magnitude of devaluation. This raises the question what determines the denomination of public debt. This issue is related to the recent literatures on “original sin” (e.g. Eichengreen and Hausmann (forthcoming)), “sudden stops” (e.g. Calvo (2003)) and public bailout guarantees for private contracts in a foreign currency (e.g. Burnside, Eichenbaum and Rebelo (2000)). Second, what factors constrain fiscal reform and monetary policy after a fiscal shock? Political economy and concerns about financial stability are promising areas of analysis. Third, many devaluations coincide with both fiscal stress and sharp changes in output. The focus of this paper is on the former, while some recent models emphasize the latter.²⁵ We regard our contribution as a building block toward future models that will simultaneously account for both aspects of crises.

²⁵Examples are: Aghion, Bacchetta, and Banerjee (2003), Caballero and Krishnamurthy (2001), Chang and Velasco (2001), Gertler, Gilchrist, and Natalucci (2003) and Schneider and Tornell (2000).

A Appendix

We discuss the behavior of the single-good model with the more general post-devaluation interest rate rule (11) and with $P_\beta^* = P_\alpha^*$. There isn't now a closed-form solution for the equilibrium exchange rate, the difficulty being that the perpetuity price in the period of devaluation no longer equals $(1/i^p)$ as in the main text. Nevertheless, it is interesting to examine effects of a more general policy specification.

Given the interest rate rule (11) with $\beta\phi_1 < 1$, equilibrium condition (2) becomes a stable difference equation in the (gross) depreciation rate upon the jump in the exchange rate in period $\tilde{T} \geq t$:

$$\frac{\mathcal{E}_{\tilde{T}+s+1}}{\mathcal{E}_{\tilde{T}+s}} = \beta\phi_0 + \beta\phi_1 \frac{\mathcal{E}_{\tilde{T}+s}}{\mathcal{E}_{\tilde{T}+s-1}} \quad (20)$$

where $s \geq 0$. Once we know the exchange rate at the time of the crisis $\mathcal{E}_{\tilde{T}}$, (20) determines the post-devaluation evolution of the exchange rate, and (2) determines the post-devaluation path of nominal interest rates. Notice that the (gross) depreciation rate converges to:

$$\frac{\beta\phi_0}{1 - \beta\phi_1}$$

which is, given our assumption $\beta\phi_0 \geq 1 - \beta\phi_1$, greater than or equal to 1. $\phi_1 = 0$ is a pure interest rate peg analyzed in the main text. With $\phi_1 = 0$ and $\phi_0 = \beta^{-1}$, the exchange rate jumps in period \tilde{T} and remains at $\mathcal{E}_{\tilde{T}}$ permanently — the steady state depreciation rate is zero. For other parameter values, the exchange rate jumps in period \tilde{T} and then the depreciation rate converges to its limiting constant value. Greater values of policy parameters ϕ_0 and ϕ_1 imply that the nominal interest rate and the depreciation rate are higher in the post-devaluation steady state. A larger ϕ_1 causes more persistent effects of the initial jump in \mathcal{E} on interest and depreciation rates.

Using equilibrium condition (2) and policy rule (11), we derive:

$$1 + i_{\tilde{T}+s} = \phi_0 \left(\sum_{j=0}^s \phi_1^j \beta^j \right) + \phi_1 (\phi_1 \beta)^s \left(\frac{\mathcal{E}_{\tilde{T}}}{\mathcal{E}} \right)$$

where $\tilde{T} \geq t$ is the collapse time, and $s \geq 0$. We note that the (gross) nominal interest rate converges to $\phi_0/(1 - \phi_1\beta)$ as $s \rightarrow \infty$. We substitute the above equation into equilibrium

condition (4) to obtain an expression for $\theta_{\tilde{T}}$ in terms of $\mathcal{E}_{\tilde{T}}$ and policy parameters ϕ_0 and ϕ_1 :

$$\theta_{\tilde{T}} = \sum_{s=0}^{\infty} \left\{ \prod_{k=0}^s \left[\phi_0 \left(\sum_{j=0}^k \phi_1^j \beta^j \right) + \phi_1 (\phi_1 \beta)^k \left(\frac{\mathcal{E}_{\tilde{T}}}{\bar{\mathcal{E}}} \right) \right]^{-1} \right\} \quad (21)$$

where $\tilde{T} \geq t$. Since policy raises interest rates in response to devaluation and this tends to reduce the long-term bond price, the above expression is a decreasing relationship between $\left(\mathcal{E}_{\tilde{T}}/\bar{\mathcal{E}} \right)$ and $\theta_{\tilde{T}}$. For a given $\left(\mathcal{E}_{\tilde{T}}/\bar{\mathcal{E}} \right)$, higher values of ϕ_0 and ϕ_1 imply a smaller $\theta_{\tilde{T}}$.

Suppose the exchange rate jumps in period $\tilde{T} = t$. Putting together (9) and (10) yields an increasing equilibrium relationship between $\left(\mathcal{E}_t/\bar{\mathcal{E}} \right)$ and θ_t , implied by the solved-forward government budget constraint:

$$\left\{ \frac{[1 + (1/r)] L_{t-1} + (1+r) B_{t-1}}{\bar{\mathcal{E}}} - \Delta \right\} \left(\frac{\mathcal{E}_t}{\bar{\mathcal{E}}} \right) = \frac{(1 + \theta_t) L_{t-1} + (1+r) B_{t-1}}{\bar{\mathcal{E}}}$$

The above equation and (21) with $\tilde{T} = t$ uniquely determine $\left(\mathcal{E}_t/\bar{\mathcal{E}} \right)$. Higher values of ϕ_0 and ϕ_1 act like a higher i^p in the main text, and are associated with a lower $\left(\mathcal{E}_t/\bar{\mathcal{E}} \right)$ in equilibrium.

Consider now a delayed devaluation, i.e. suppose the exchange rate jumps in period $\tilde{T} > t$. The unique solution for $\left(\mathcal{E}_{\tilde{T}}/\bar{\mathcal{E}} \right)$ is found by combining (13) and the following version of (14):

$$\theta_t = \frac{1}{r} + \left(\frac{1}{1+r} \right)^{\tilde{T}-t-1} \left(\frac{1 + \theta_{\tilde{T}}}{(1+r) \left(\mathcal{E}_{\tilde{T}}/\bar{\mathcal{E}} \right)} - \frac{1}{r} \right)$$

with (21) substituted for $\theta_{\tilde{T}}$. Again, higher values of ϕ_0 and ϕ_1 act like a higher i^p in the main text and are associated with a lower $\left(\mathcal{E}_{\tilde{T}}/\bar{\mathcal{E}} \right)$ in equilibrium.

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Figure 1: The dynamics of the exchange rate - an illustrative example

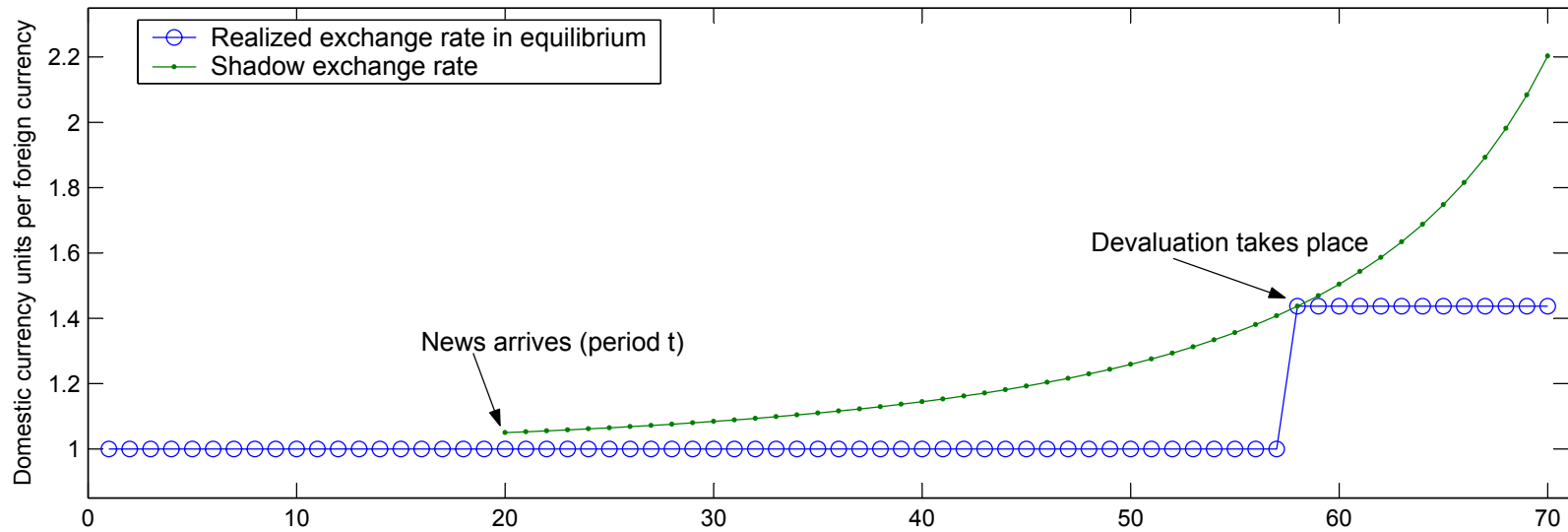


Figure 2: The dynamics of the short-term nominal interest rate - an illustrative example

