# A Corporate Balance-Sheet Approach to Currency Crises[1]

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**Abstract**

This paper presents a general equilibrium currency crisis model of the 'third generation', in which the possibility of currency crises is driven by the interplay between private firms' credit-constraints and nominal price rigidities. Despite our emphasis on microfoundations, the model remains sufficiently simple that the policy analysis can be conducted graphically. The analysis hinges on four main features i) ex post deviations from purchasing power parity; ii) credit constraints a la Bernanke-Gertler; iii) foreign currency borrowing by domestic firms; iv) a competitive banking sector lending to firms and holding reserves and a monetary policy conducted either through open market operations or short-term lending facilities. We derive sufficient conditions for the existence of a sunspot equilibrium with currency crises. We show that an interest rate increase intended to support the currency in a crisis may not be effective, but that a relaxation of short-term lending facilities can make this policy effective by attenuating the rise in interest rates relevant to firms.

# 1 Introduction

Researchers in recent years have had to grapple with the puzzle of how fast-growing economies with large export surpluses and substantial government surpluses, could end up in the space of months, in a deep and damaging currency crisis. This paper builds on a very simple story of why things fall apart quite so dramatically if domestic prices do not adjust fully to exchange rate changes in the short run, a currency depreciation leads to an increase in the debt burden of domestic firms that borrowed in foreign currency, and consequently a fall in profits.[1] Since lower profits reduce net worth, this may result in reduced investment by credit-constrained firms, and therefore in a lower level of economic activity in the following period. This, in turn, will bring a fall in the demand for money, and thus a currency depreciation in that next period. But arbitrage in the foreign exchange market then implies that the currency must depreciate in the current period as well. Hence the possibility of multiple short run equilibria in the market for foreign exchange. A currency crisis occurs when an expectational shock pushes the economy into the "bad" equilibrium with low output and a high nominal exchange rate.

This story is compelling for a number of reasons. First, there is evidence that foreign currency exposure is correlated with the likelihood of a crisis in particular, Hausmann, Panizza, and Stein (2000) show that the countries most likely to go into a crisis were those in which firms held a lot of foreign currency denominated debt.[2] Second, there is strong evidence that exchange rate changes are incorporated into domestic prices relatively slowly. For example, Goldfajn and Werlang (2000) compute the pass-through from exchange rate to prices in a set of 71 countries including both developed and less developed countries. They show that the pass-through is very gradual and tends to be even smaller after currency crises—in the Asian crises, for example, less than 20% of currency depreciation was reflected in inflation after 12 months. Third, it is widely accepted that an important link between

[1] The damaging impact of foreign currency debt is often mentioned in the context of currency crises. See, for example, Cooper (1971), Calvo (2000) and Mishkin (1996, 1999). While the role of foreign currency *public* debt has received some attention in the theoretical literature on crises (e.g. Bohn, 1990, Obstfeld, 1994, Falcetti and Missale, 1999), the impact of private foreign currency debt has hardly been analyzed (see, however, Jeanne, 2000).

[2] See also Honkapohja and Koskela (1999) for the Finnish case.

the currency crises and the subsequent fall in output was a financial crisis which affected the ability of private firms to finance production—indeed this is why the crises are often described as triple (currency, financial, output...) crises.[3] Fourth, the model predicts that such crises are most likely to occur in economies at an intermediate level of financial development (i.e., not in the US and not in Burma) and cannot be ruled out by what are conventionally viewed as prudent government policies, which in turn seems consistent with the facts.

This is not the first paper to tell a story of this kind. Our earlier papers on the subject (Aghion, Bacchetta and Banerjee, 2000, 2001a) feature the same basic story, as does the related paper by Krugman (1999b). In this paper we delve deeper into the story by integrating the monetary side of the economy together with its credit side, through the natural channel of modeling the needs of the banking sector for reserves. This is important because a key question in these papers has been the role of monetary policy in a crisis, and this obviously depends crucially on how monetary policy affects firms' access to credit.[4] Moreover, explicitly modeling the relation between the central bank and the banking sector, naturally leads us to consider a richer menu of monetary policy instruments than is standard in the literature. We are thus able to ask questions about the optimal mix of monetary policy instruments in a crisis Interestingly, it turns out that it may be optimal to tighten money supply through open market operations but at the same time to ease the supply of emergency credit to banks through the so-called discount window.

There are a number of other recent papers which have studied the issue of monetary policy in related contexts. Apart from our own previous papers already mentioned above, the most closely related literature includes Gertler,

[3]Most attempts to make sense of the latest crises have been based on the idea that a crisis affects output through its effect on access to credit in the firm sector. See for example, Aghion, Bacchetta, and Banerjee (1999a,b) Krugman (1999a), Chang and Velasco (2000), Caballero and Krishnamurty (2001). The key difference between these papers and the current paper is these are real models, whereas we stress the monetary elements in our story.

[4]In our previous two papers monetary policy could only have any real effects through changes in the real exchange rate. In Aghion, Bacchetta and Banerjee (2000) we introduced such a real effect by directly assuming that a tighter monetary policy raises the real costs of lending, which in turn would lead to the conclusion that a tight monetary policy might not always be a good thing. Here, instead, the assumed effect of monetary policy on the real cost of lending is generated from a model where the lending banks optimally choose their cash holdings.

Gilchrist and Natalucci (2000), Cespedes, Chang and Velasco (2000) and Christiano, Gust and Roldos (2002). All of these papers share the conclusion that even in a crisis it may be a good idea to let the exchange rate go down further. Gertler et al. and Cespedes et al. interpret this result as supporting the case for flexible exchange rates over fixed exchange rates, while Christiano et al. see it as a case for relaxing monetary controls in a crisis even at the cost of an exchange rate depreciation. The one important difference between these papers and ours is that they operate in an environment where there is a unique equilibrium. In Aghion, Bacchetta and Banerjee (2001a) we had shown that there are circumstances where the equilibrium is always unique and in such cases, the case for taking a relaxed monetary stance and letting the exchange rate float down is much stronger, consistent with the message of these papers. In contrast, our analysis in this paper focuses exclusively on the multiple equilibrium case.

The paper is organized as follows. Section 2 lays out the general framework, including the borrowing and investment decisions of domestic manufacturing firms, and endogenizing their credit constraints. Section 3 describes the monetary side of the economy; in particular, it derives the demand for reserves by banks in relation to the supply of credit to domestic manufacturing firms, thereby generating a reserves market equilibrium equation. Together with interest parity, this equation determines a relationship from future expected output to current nominal exchange rate which we refer to as the "IPLM" (or "interest-parity-LM") curve. Section 4 concentrates on the real side of the economy, which leads to expressing future output as a function of the current nominal exchange rate; we refer to this second relationship between those two variables, as the "W" (or "wealth") curve. Section 5 analyzes the sunspot equilibria of this model; in particular it provides sufficient conditions for the existence of non-deterministic sunspot equilibria, and thus for the occurrence of expectational shocks and the possibility of currency crises. Section 6 uses a simple graphical representation of the model to discuss the stabilization effects of open market operations and of discount window-types of policies. Finally, Section 7 concludes by suggesting potential extensions.

# 2 General Framework

We consider an infinite-horizon, small, open, monetary economy with two production sectors, an import-competing manufacturing and an exporting commodity sector. There are four types of agents in the economy entrepreneurs who produce manufacturing goods; non-entrepreneurs who can either work for the manufacturing sector at a preset wage, or work on their own to produce commodities according to a linear one-for-one technology; commercial banks that lend to the entrepreneurs and hold reserves; and the central bank that runs monetary policy with open market operations or short-term lending facilities.

Entrepreneurs in the manufacturing sector produce differentiated goods, but in a symmetric fashion with the same production function and the same inverse demand function. In addition, all manufacturing firms share the following two characteristics First, they preset prices for each period before the actual exchange rate is known; to save on menu costs they maintain the price fixed for the entire period. Second, they borrow from banks, but the credit contract is only partially enforceable, which generates a constraint on how much the firm can borrow. Moreover, they prefer borrowing in foreign currency due to moral hazard. Finally, we shall restrict attention to the case where the domestic demand for manufacturing goods is always larger than their domestic production. We assume that for each manufacturing good there are international producers who are ready to sell it in the domestic market. Thus, changes in demand are accommodated by foreign producers who act as a competitive fringe and sell at a constant price equal to one unit of the foreign currency.

An unexpected currency depreciation has a negative aggregate impact on output in our model through an increase in the foreign currency debt burden. Although exporters gain from the depreciation, it is the import-competing sector that determines the dynamics of output.

At the heart of the theoretical model is the possibility of multiple expectational equilibria. In other words, a 'sunspot' is realized, causing expectations to shift during the period. The model produces a *non-degenerate* sunspot equilibrium in which the equilibrium exchange rate in period 1, $S_1$, is randomly distributed and equal to a low value $S_1'$ with probability $1 - q$ and to a high value $S_1''$ with probability $q$, with $S_1'' > S_1'$ and $q$ being small. When the exchange rate takes the high value $S_1''$, manufacturing output is low and firms are unable to meet their debt obligations. We shall refer to this state of nature as a currency crisis.

Purchasing power parity (PPP) will be assumed to hold ex ante at the beginning of every period, and the only deviation from PPP ex post will be in period 1 in the manufacturing sector as a result of the expectational shock not being accommodated at once by domestic price-setting in that sector.

## 2.1 Sequence of Events

The timing of events can be summarized as follows. Manufacturing prices are fixed at the beginning of each period $t$ for the entire period, while the other variables are determined at the end of the period. First, the expectational shock occurs, to which corresponds a realization of the nominal exchange rate $S_t$. The shock is accompanied by an adjustment in the monetary policy set by the central bank and it also affects the demand for reserves ($h_t$) from commercial banks. This in turn affects the lending rate $i_t^l$ charged by banks to firms in period $t+1$. Entrepreneurs then decide whether or not to repay their debt from the previous period and choose the fraction $\beta$ of their net earnings that they will save. With these savings $w_t$, entrepreneurs decide how much to borrow for the subsequent period ($l_{t+1}$) and how much to invest ($w_{t+1} + l_{t+1}$). We will focus on the case where expectational shocks on the nominal exchange rate $S_t$ only occur in the first period and where there is a unique equilibrium exchange rate in all subsequent periods.

## 2.2 Production Technology

All manufacturing firms produce according to the same Cobb-Douglas technology $y_t = A_t k_t^{\alpha} n_t^{1-\alpha}$, where $n_t$ and $k_t$ denote respectively the labor and capital inputs in period $t$. $k_t$ is working capital made of manufactured goods that fully depreciates at the end of the period. Since labor supply to manufacturing firms is perfectly elastic at real wage $\omega$, in equilibrium we have

$$y_t = \sigma_t k_t, \quad \text{where} \quad \sigma_t = A_t \left( \frac{(1-\alpha)A_t}{\omega} \right)^{\frac{1-\alpha}{\alpha}} > 1 + r_t,$$

where $r_t$ is the real rate of return on bonds. Note that sales net of wage payments are $\alpha y_t$, as the optimal demand for labor gives $\omega n_t = (1-\alpha) y_t$. We will focus on the case where $A_t \equiv A$ (and therefore $\sigma_t \equiv \sigma$) for $t \geq 2$, with $\sigma$ being sufficiently larger than $\sigma_1$ so that if expectational shocks and multiple sunspot equilibria can occur in period 1, yet there will be a unique deterministic equilibrium in all subsequent periods.

## 2.3 Savings and Consumption Behavior

All individuals in the domestic economy, including the domestic entrepreneurs who produce manufacturing goods, will choose their intertemporal consumption pattern ($c_j$) and also the fraction of wealth ($x_j$) they invest in their own manufacturing activity versus investing in bonds to maximize their expected lifetime utility[5]

$$\max_{x_j, c_j} \sum_{j=t}^{\infty} \beta^j E_t \ln(c_j)$$

$$s.t. \qquad w_{j+1} = x_j M_j(S_j) w_j + (1 - x_j)(1 + r_j) w_j - c_j$$

where $c_j$ is an aggregate consumption index for manufactured goods at date $j$, $w_{j+1}$ is the entrepreneur's savings at the beginning of period $j + 1$, and $M_j(S_j)w_j$ is the ex post revenue in period $j$.[6]

Using the above budget constraint to substitute for the $c_j$'s, and then taking first order conditions with respect to $x_j$ and $w_j$ for all $j$, we will show in Section 4 ( in particular in footnote 21) that for $\sigma_1$ and $\sigma$ sufficiently large and $q$ sufficiently small, we have[7]

$$x_j \equiv 1.$$

Throughout the paper we shall restrict attention to parameter values such that in equilibrium entrepreneurs do indeed prefer to invest their savings in their own projects rather than in government bonds or in bank deposits.

This, together with the logarithmic preference assumption, implies that entrepreneurs will always consume a constant fraction $1 - \beta$ of the revenues

[5] They could also derive utility from the homogenous commodity, but we assume, without loss of generality, that their optimal consumption of the commodity is equal to zero. Entrepreneurs may also incur some disutility or some private benefits from producing, but this has no bearing on the analysis insofar as the corresponding cost or benefit is fixed.

[6] Since in equilibrium manufacturing output is a linear function of capital investment, $M_j(S_j)$ is independent of $w_j$. We shall restrict attention to sunspot equilibria in which $S_1$ can take two values, $S_1'$ and $S_1''$, respectively with probability $(1 - q)$ and $q$, such that manufacturing firms may default when $S_1 = S_1''$, whereas the $S_j$'s are deterministic for all $j \geq 2$. Thus, $M_j(S_j)$ is also random in period $j = 1$, but not in subsequent periods. Finally, we assume that domestic entrepreneurs can always choose to divert a positive fraction of output, which in turn implies that $M_j(S_j)$ is bounded away from zero.

[7] Consistency with the existence of non-degenerate sunspot equilibria is established in Section 5.

generated by their own projects, namely

$$w_{t+1} = \beta M_t w_t \qquad c_t = (1-\beta) M_t w_t.$$

Within each period $t$, the consumption index $c_t$ results from an intra-period utility with constant elasticity of substitution between differentiated manufacturing goods.

$$c_t = \left[ \int_0^1 c_t(i)^{\frac{\nu-1}{\nu}} di \right]^{\frac{\nu}{\nu-1}},$$

where $c_t(i)$ is the individual consumption of manufactured good $i$ in period $t$ and $\nu$ is the elasticity of substitution between any two manufacturing goods, which in turn we take to be larger than one. A consumer's total nominal consumption at date $t$ is

$$\int_0^1 p_t(i) c_t(i) di = \Psi_t$$

where $\Psi_t$ represents total nominal expenditures and $p_t(i)$ is the price of good $i$ at time $t$.

The resulting individual demand for manufactured good $i$ is therefore

$$c_t(i) = \left( \frac{p_t(i)}{P_t} \right)^{-\nu} \frac{\Psi_t}{P_t}$$

where $P_t$ is the consumer price index for domestic manufactured goods with $P_t = \left[ \int_0^1 p_t(i)^{1-\nu} di \right]^{1/(1-\nu)}$.

## 2.4 Price Setting

While PPP holds at any time for commodities and ex ante for all goods, it does not hold *ex post* in period 1 in the manufacturing good sector. This follows, first from the assumption that the price of manufacturing goods is preset in domestic currency for one period to save on menu costs;[8] and, second, from the assumption that consumers cannot arbitrage *ex post* between domestic and foreign producers. Arbitrage (within an industry) is possible *ex ante*, so that PPP holds *ex ante* for all manufacturing goods.

[8] This is a standard assumption in the 'new open economy macroeconomics' literature. See for example Obstfeld and Rogoff (1995, 1996) and Bacchetta and van Wincoop (2000).

We shall restrict attention to the case where $c_t(i) > y_t(i)$ for all $(t, i)$, so that the manufacturing sector is always import competing and for each good $i$ there is a domestic producer and a set of foreign producers. We assume that consumers first precommit on a quantity and a price with domestic producers. Then, risk-neutral foreign producers compete Bertrand on the residual market segment and set the price in domestic currency.[9] If we normalize their marginal cost (in foreign currency) at 1, their price is $S_t^e$. The domestic producer has to set the same price to attract consumers (*ex ante* arbitrage) and sell the quantity determined by their credit constraint. Thus, we simply have $p_t(i) \equiv P_t \equiv S_t^e$. Finally, since the quantity sold by domestic producers is pre-determined, changes in manufacturing goods demand are entirely met by changes in imports, with foreign producers always ready to satisfy domestic demand at the preset price $P_t$.

While manufacturing prices are sticky, the domestic currency price of commodities is assumed to be flexible in any period $t$ and simply equal to $S_t\omega$, where $\omega$ denotes the foreign currency commodity price which we take to be constant and equal to $\omega$. If non-entrepreneurs choose to devote one unit of labor to produce one unit of commodity which they sell on the world markets, they get $S_t^e\omega = P_t\omega$. Thus, they will work in the manufacturing sector if the real wage offered by domestic entrepreneurs is at least equal to $\omega$.

## 2.5 Credit

### 2.5.1 Interest Parity

The exchange rate is determined by investors arbitraging between domestic and foreign currency bonds; we assume full capital mobility, so that uncovered interest parity (IP) is assumed to hold perfectly[10]

$$1 + i_t = (1 + i^*)\frac{S_{t+1}^e}{S_t} \tag{1}$$

[9] The strategy of pricing to market in domestic currency is taken as given. Bacchetta and van Wincoop (2002) provide conditions under which this strategy is optimal.

[10] The uncovered interest parity applies with risk neutrality as it is the outcome of arbitrage from fully diversified international investors.

### 2.5.2 The Debt Contract

A firm's capital investment in any period $t$ is made of the entrepreneur's own wealth $w_t$ and of additional funds borrowed from a bank $l_t$. Our model will rely heavily on balance-sheet effects in the spirit of Bernanke-Gertler (1989), which in our framework shows up as a positive relation between $l_t$ and $w_t$. We now derive some properties of this relationship and other properties pertaining to the currency composition of debt, based on the model of ex post moral hazard in the credit market developed by Aghion, Banerjee, and Piketty (1999).

We imagine a world where credit contracts are only partially enforceable. First, the borrower is protected by a kind of limited liability he always retains at least a fraction $\varphi$ of his revenue *from production* in all states, including the ones where there is involuntary default, i.e., when he does not have enough money to meet his debt obligation. This is the amount he can simply divert without being found out afterwards.

Second, the borrower has the option of voluntarily defaulting on any specific loan even if he has the money to repay. In other words, he can refuse to repay the loan. When this happens, the lender can collect any collateral that the borrower has pledged to her in lieu of the interest payment. However we assume that future output from production cannot be pledged the borrower can always hide the proceeds from production, though in the process a fraction $\tau$ is lost. Yet the lender can still try to get her money back by putting effort into debt collection. Specifically, by incurring a nonmonetary effort cost $l \cdot C(\psi)$, where $C(\psi) = -c\ln(1-\psi)$ and $l$ is the size of the loan, the lender can appropriate a fraction $\psi$ of her due repayment (as long as the borrower has the money).

Finally, loan contracts are short-term and there is perfect competition among lenders, so that entrepreneurs have full bargaining power upon contracting their loans.

These assumptions together determine the structure of the loan contract in equilibrium. This is what we investigate in the remaining part of this sub-section.

**The credit multiplier** Consider first the strategic default decision on a loan that is invested in production. The entrepreneurs' real income after wage and debt repayment in a particular state of the world is $\alpha y_{t+1} - R_t l_{t+1}$, where $R_t l_{t+1}$ is the real interest rate obligation in that state of the world. He will not choose strategic default in period $t+1$ if and only if

$$\alpha y_{t+1} - R_t l_{t+1} \geq \alpha(1-\tau) y_{t+1} - \psi R_t l_{t+1},^{11} \tag{2}$$

or equivalently

$$\alpha\tau \geq (1-\psi) R_t \frac{l_{t+1}}{y_{t+1}}.$$

Now, turning to the choice of the optimal monitoring policy $\psi$, the lender will choose $\psi$ to maximize

$$\psi R_t + c \ln(1-\psi),$$

so her optimal choice of $\psi$ is given by the first order condition

$$(1-\psi) R_t = c.$$

Substituting for $(1-\psi)R_t$ in the borrower's incentive constraint, we immediately obtain

$$\frac{l_{t+1}}{y_{t+1}} \leq \frac{\tau\alpha}{c}$$

This gives us a relation between the borrower's predicted future income and the amount he can borrow on the strength of it. To see how this translates into a borrowing constraint, we make use of the fact that the loan is invested in production so that $y_{t+1} = \sigma_{t+1}(l_{t+1} + w_{t+1})$. In this case, we immediately see that

$$\frac{l_{t+1}}{w_{t+1}} = \frac{\tau\alpha\sigma_{t+1}}{c - \tau\alpha\sigma_{t+1}} = \mu_{t+1}.$$

Notice that the credit multiplier $\mu_t$ depends only on $\sigma_t$ and since $\sigma_t$ is known when the loan is being allocated, $\mu_t$ is independent of what happens within the period. As a result, a borrower who is lent more than $\mu_t w_t$ will strategically default *in every state of the world where he has anything to repay* (what he does when he generates no revenues, is irrelevant). We now assume that $c$ is sufficiently large that the lender would never consider lending to a borrower who is planning to refuse to repay. Therefore a borrower who is planning to invest only in production will be lent at most $\mu_t w_t$.

[11] The LHS (resp. RHS) is the borrower's net revenue if he repays (resp. if he refuses to repay) his debt. The RHS assumes that the borrower does hide the proceeds from production.

**Foreign versus Domestic Currency Borrowing** The fact that firms borrow in foreign currency plays a crucial role in our analysis. While this accords well with what we observe in many emerging market economies, it does require a justification. In Burnside, Eichenbaum and Rebelo (2000) or Schneider and Tornell (2000), foreign currency borrowing follows from the assumption that domestic banks are bailed out by the government in case of default, so that firms will want to increase their risk exposure by borrowing in foreign currency. Jeanne (1999a, b, 2000) develops models in which foreign currency borrowing serves as a signaling or as a commitment device. In Chamon (2001) foreign currency borrowing follows directly from the extrinsic exchange rate uncertainty together with the assumption that the currency composition of a borrower's portfolio is not contractible. In Aghion-Bacchetta-Banerjee (2001b) we generalize Chamon's result to the case of credit-constrained firms. The basic intuition there is that firms prefer borrowing in foreign currency due to the following moral hazard consideration foreign currency debt implies a lower interest rate in the good state of the world, but a much larger repayment in the bad state; however, in the bad state firms default and only partially repay their debt.

# 3 The Monetary Sector

## 3.1 The Demand for Reserves

Domestic banks play a crucial role in this economy since they both channel credit to firms and hold reserves, and are therefore at the center of the monetary transmission mechanism. There is perfect competition in the banking sector. Furthermore, we assume that banks have enough assets not to fall into insolvency in case a currency crisis occurs.

Banks receive deposits $d_t$ from non-entrepreneurs and possibly foreigners, lend $l_t$ to firms and hold an amount of reserves $h_{t-1}$ in the central bank at the beginning of period $t$.[12] Thus, $d_t = h_{t-1} + l_t$. Deposits in period $t$ yield the risk-free nominal domestic interest rate $i_t$. We assume that banks only take deposits to cover their lending and reserves needs.[13]

[12] The difference in timing notation between monetary and real-sector variables is imposed by consistency with the interest parity condition (the nominal interest rate determined at the end of $t-1$, but valid for period $t$, is $i_{t-1}$).

[13] We abstract from liquidity needs from depositors so that they are indifferent between

We assume that banks' demand for reserves is linked to the supply of credit to the manufacturing sector more specifically, suppose that with probability $\lambda$ a manufacturing firm faces an aggregate liquidity shock (e.g., due to the fact that its workers need to be paid in cash early in the period instead of waiting until the end of the production period). We assume that the liquidity need is proportional to the amount $l_t$ borrowed by the firm at the beginning of the period, $\gamma l_t$. Thus, with each loan $l_t$ a bank needs to provide liquidity $\gamma l_t$ to the borrowing firm with probability $\lambda$. If the lending bank does not fulfil this liquidity need, the firm cannot produce nor repay its outstanding debt.[14]

Banks can get liquidity by holding reserve deposits at the central bank in quantity $h_t$. However, these reserves do not bear interest and thus have an opportunity cost of $i_t$. Alternatively, banks can borrow at the discount window at a penalty rate $\widetilde{\theta}_t$. The optimal holdings of reserves by banks in period $t$ for period $(t+1)$ is determined by the following cost minimization program in which banks weigh the cost of holding reserves against that of borrowing at the discount window

$$\min_{h_t} \left\{ i_t h_t + \lambda(\gamma l_{t+1} - h_t)\widetilde{\theta}_t \right\}.$$

We assume that this rate increases with the proportion of liquidity which is borrowed. For analytical convenience, we assume a linear relationship $\widetilde{\theta}_t = \theta_t \cdot ((\gamma l_{t+1} - h_t)/\gamma l_{t+1})$, where $\theta_t$ is what we call the discount window rate and can be changed by the central bank to modify monetary policy.[15] The

holding bank deposits or domestic bonds. There is also no transaction cost for banks to receive deposits. Alternatively, banks could also hold bonds and raise more deposits.

[14] The liquidity need is assumed to be ex ante the same in all periods. An interesting extension would be to model this liquidity need and relate it to crises.

[15] An alternative interpretation of the parameter $\theta$ is that it reflects a quantity restriction imposed by the central bank to the commercial banks. For example suppose that the central bank commits itself to refinancing up to a fraction $\delta$ of a bank's liquidity need $\gamma l_t$, where $\delta$ is uniformly distributed between 0 and $D$. And let $b$ denote the private loss incurred by the bank or the bank's manager if the liquidity need is not fully met. Then, the cost minimization problem will be identical to that stated above, but with $\theta = \frac{b}{D}$; in particular a tighter quantity restriction on refinancing, that is a lower $D$, amounts to increasing $\theta$.

optimal *demand* for reserves is then simply given by[16]

$$h_t = \gamma l_{t+1}(1 - \frac{i_t}{2\lambda\theta_t}) = y_{t+1}\frac{\gamma\mu}{\sigma_t(1+\mu)}(1 - \frac{i_t}{2\lambda\theta_t}). \tag{3}$$

If now the central bank *supplies* a nominal quantity of reserves $H_t^S$, then the reserve or "money" market equilibrium, is characterized by the (LM) relationship

$$\frac{H_t^S}{P_t} = h_t. \tag{4}$$

## 3.2 Monetary Policy

In most of the paper, we assume that the central bank sets $i_t$ and $\theta_t$. However, there is still a degree of freedom to set the level of the nominal money stock. For convenience, we assume that the central bank sets $H_2^S$, while $H_t^S$ is endogenous in the other periods. We could have alternatively set $H_3^S$ or $H_4^S$, or any single future value of $H_t^S$: The important assumption is not that $H^S$ is set in a particular period, but that this level is not state contingent.

When changes in monetary policy, that is in $\theta_t, i_t$ and/or $H_t^S$ are anticipated, then the equilibrium price $P_t$ fully adjusts to such changes. In particular, $P_2$ adjusts to the anticipated monetary policy $(H_2^S, i_2, \theta_2)$ according to equation (4). For all $t \geq 3$, given a sequence of monetary policies $(i_t, \theta_t)$, equilibrium prices $P_t$ are sequentially pinned down by the Interest Parity conditions $1 + i_t = (1+i^*)P_{t+1}/P_t$, since $P_t = S_t^e = S_t$ for all $t \geq 2$.

However, when changes in monetary policy are unanticipated, as we assume to be the case in period 1, the price level is fixed and from (3) policy variables are linked by

$$i_1 = 2\lambda\theta_1(1 - \frac{H_1^S}{\gamma P_1 l_2}). \tag{5}$$

In the equilibrium analysis of Section 5 we take $(i_1, \theta_1)$ as given, so that $H_1^S$ is determined by (5). However, in the policy analysis of Section 6, $(H_1^S, \theta_1)$ are the primary policy variables. Thus, the central bank can increase the nominal risk-free interest rate $i_1$ in two ways either by decreasing the monetary base $H_1^S$ or by increasing the discount window rate $\theta_1$ (or equivalently by tightening its limits to refinancing).

[16] See Agénor, Aizenman, and Hoffmaister (2000) for a recent estimation of a similar demand of reserves by commercial banks in Thailand.

### 3.3 The Cost of Lending

Banks lend to manufacturing firms at a nominal interest rate $i_t^{*l}$ in foreign currency units. Suppose that with probability $1 - q_t$ the bank gets back its full loan plus interest and with probability $q_t$ the firm defaults, in which case the bank gets a proportion $1 - \varphi$ of the firm's profits net of wage payments. The bank's net expected nominal earnings in domestic currency units, are therefore

$$(1 - q_t)(1 + i_t^{*l})P_t l_{t+1}\frac{S'_{t+1}}{S_t} + q_t(1 - \varphi)P_{t+1}y_{t+1}$$

Under perfect competition this should be equal to the cost of the loan. This cost, in turn, is the sum of the deposit rate paid by the bank (which, by competition, should be equal to $i_t$) and its intermediation costs. That is

$$(1 + i_t)P_t l_{t+1} + i_t P_t h_t + \lambda P_t(\gamma l_{t+1} - h_t)\widetilde{\theta}_t.$$

Equating the two above expressions, and letting $\pi_t$ and $r_t$ denote respectively the inflation rate and the real interest rate at date $t$, we get[17]

$$(1-q_t)(1+i_t^{*l})\frac{S'_{t+1}}{S_t} = (1+i_t) - q_t(1-\varphi)(1+\pi_{t+1})\frac{y_{t+1}}{l_{t+1}} + i_t\frac{h_t}{l_{t+1}} + \lambda(\gamma - \frac{h_t}{l_{t+1}})\widetilde{\theta}_t \tag{6}$$

By using (3), interest parity and the definition of $\widetilde{\theta}_t$, we then find

$$(1 + i_t^{*l}) = \frac{1 + i^*}{1 - q_t}\left[1 - q_t(1 - \varphi)\frac{\sigma(1 + \mu)}{(1 + r_t)\mu} + \gamma\frac{i_t}{1 + i_t}(1 - \frac{i_t}{4\lambda\theta_t})\right], \tag{7}$$

In particular, inflation targeting or any other policy that maintains $i_t$ constant throughout all periods $t \geq 2$, will also result in the lending rate remaining invariant throughout these periods.

Note that the lending rate $i_t^{*l}$ is influenced both by the risk-free rate $i_t$, and therefore indirectly by the supply of reserves $H_t^s$, and directly by the discount window rate $\theta_t$. As we shall see in Section 6 below, tightening the money

[17] Here we are using the fact that the inflation rate $\pi_t$ is determined by

$$1 + \pi_t = (1 + z_t)\frac{h(l_t, i_{t-1})}{h(l_{t+1}, i_t)},$$

in which $z_t$ denotes the growth rate of reserves supply at date $t$, which in turn follows directly from (4).

supply by increasing $\theta_t$ and by reducing $H_t^s$, not only have different effects on the overall equilibrium outcome, but also may end up being mutually offsetting.

### 3.4 The IPLM Curve

Using the fact that PPP holds at the beginning of every period and in particular in period 2, so that $P_2 = S_2^e$, and thereby eliminating $P_2$ between the two equations (3) and (4), we obtain the following "IPLM" relationship between $S_1$ and $y_3$

$$S_1 = \frac{1+i^*}{1+i_1} . \frac{H_2^s}{y_3 \frac{\gamma\mu}{\sigma(1+\mu)}(1 - \frac{i_2}{2\lambda\theta_2})}. \tag{8}$$

For given $i_2$, $S_1$ is a decreasing function of $y_3$. This can be simply explained as follows an anticipated increase in output amounts to an anticipated increase in the demand for reserves by the banking system in order to meet the liquidity needs of the manufacturing sector. This in turn will lead to an expected appreciation of the domestic currency in the future, that is to a reduction of $S_2^e$. But the anticipation of a currency appreciation in the future increases the attractiveness of holding domestic currency bonds today, which in turn induces a reduction in $S_1$, that is a currency appreciation today.

The negative relationship is illustrated in Figure 1. From the IPLM equation, we see that a restrictive monetary policy at time 1 shifts the curve downwards through an increase in $i_1$ for a given future output, a restrictive monetary policy implies a currency appreciation.

## 4 The Real Sector

In this section we determine the dynamics of output and provide a graphical representation between third period output and period one nominal exchange rate.

### 4.1 Net Profits and Wealth Dynamics

Let $i_{t-1}^{*l}$ denote the lending rate charged at time $t$ by banks to domestic manufacturing firms which borrow in foreign currency. Using the interest parity condition to express the debt obligation of firms in units of the domestic currency, assuming that in case of default a positive fraction $\varphi$ of a firm's output cannot be appropriated by its lenders,[18] and allowing for strategic default, nominal profits are

$$\Pi_t = \max\{\alpha P_t y_t - (1 + i^{*l}_{t-1})\frac{S_t}{S_{t-1}} P_{t-1} l_t, \alpha\varphi P_t y_t\},$$

or equivalently

$$\Pi_t = P_t M_t w_t, \tag{9}$$

where $M_t$ is the real rate of return on investment

$$M_t = \max\{\alpha\sigma_t(1 + \mu) - (1 + i^l_{t-1})\frac{S_t}{S_{t-1}}\frac{P_{t-1}}{P_t}\mu, \alpha\varphi\sigma_t(1 + \mu)\}.$$

The second term in the curly bracket is what accrues to the firm in case of default, under the assumption that entrepreneurs first pay workers and then lenders can seize a proportion $1 - \varphi$ of the remaining funds. Thus, entrepreneurs are left with $\varphi\alpha y_t$.[19] We shall be particularly interested in non-deterministic sunspot equilibria where strategic default occurs in period 1, whenever the domestic currency experiences a large depreciation with an exchange rate realization $S''_1$ becoming correspondingly high.

Given the optimal savings behavior of entrepreneurs as described in Section 2.3, if productivity $\sigma_t$ is sufficiently high and the probability of default $q$ is sufficiently small,[20] entrepreneurs will invest all their savings in their own

[18] This fraction is naturally interpreted as reflecting monitoring imperfections on the lending side.

[19] Here we allow for both genuine and strategic default. Genuine default occurs when the first term in the curly bracket is negative, while strategic default will occur whenever the first term in the curly bracket is less than the second term.

[20] A sufficient condition for domestic entrepreneurs to invest all their savings in their own project instead of investing them in government bonds, is that $q$ be sufficiently small and

$$\alpha P_t\sigma_t(1 + \mu) - (1 + i^{l*}_{t-1})\frac{S_t}{S_{t-1}} P_{t-1}\mu > (1 + i)P_{t-1},$$

where $i^{l*}_{t-1}$ is determined by equation (7). For $q$ sufficiently small, this condition is implied by the stronger condition

$$\alpha\sigma_t(1 + \mu) > (1 + i^*)(1 + \mu + \gamma),$$

or equivalently

$$(C_0)\alpha\sigma_t > (1 + i^*)(1 + \frac{\gamma}{1 + \mu}).$$

manufacturing projects and total net wealth available for the next production period $t+1$ will then be given by

$$w_{t+1} = \beta \frac{\Pi_t}{P_t}.$$

Focusing on a potential crisis occurring at time 1, let us look at entrepreneurs' wealth at time 2

$$w_2 = \beta \max\{\alpha\sigma_1(1+\mu) - (1+i_0^{*l})\frac{S_1}{P_1}\mu, \alpha\varphi\sigma_1(1+\mu)\}w_{1.} \tag{10}$$

A currency depreciation clearly has a negative impact on $w_2$ as it increases entrepreneurs' debt burden.[21] Given our assumption that in subsequent periods $t \geq 2$, the productivity parameter $\sigma_t \equiv \sigma$ is sufficiently large that no expectational shocks can occur, interest parity will hold throughout these periods and firms will not find it profitable to default on their debt obligations. Thus, for period 3 we have

$$w_3 = \beta(\alpha\sigma(1+\mu) - (1+i_1^{*l})\frac{P_1}{S_1}\mu)w_{2.} \tag{11}$$

The positive effect of $S_1$ on $w_3$ for given $w_2$, stems from the fact that a devaluation in period 1 predicts a real appreciation in the following period. This, in turn, has the effect of lowering the real interest rates on bonds and investments in period 2, thereby increasing the retained earnings that firms can invest at the beginning of period 3.

For all subsequent periods ($t > 2$) we have

$$w_{t+1} = \beta(\alpha\sigma(1+\mu) - (1+i^{*l})\mu)w_t = \beta M w_t, \tag{12}$$

where the lending rate $i^{*l}$ remains also constant under inflation targeting or any other policy that will maintain $i_t$ constant for $t \geq 2$. This equation shows that output in subsequent periods is unaffected by the nominal exchange rate (a natural consequence of the fact that there is no deviation from PPP throughout these periods).

[21] The model could be extended by introducing stronger competitiveness effects, for example with an exporting sector that has characteristics similar to those of the import-competing sector. Since competitiveness effects are well understood, we do not incorporate them in our model and focus instead on foreign currency debt effects.

## 4.2 The W curve

Combining (10), (11), and the fact that $y_3 = \sigma(1+\mu)w_3$, we obtain

$$\begin{aligned} y_3 &= \beta^2\sigma(1+\mu)(\alpha\sigma(1+\mu) - (1+i_1^{*l})\frac{P_1}{S_1}\mu) \cdot \\ & \max\{\alpha\sigma_1(1+\mu) - (1+i_0^{*l})\frac{S_1}{P_1}\mu, \varphi\alpha\sigma_1(1+\mu)\}w_{1.} \end{aligned} \tag{13}$$

This gives a second relation between $S_1$ and $y_3$, which we will call the W curve. It is depicted in Figure 2. We see that it is composed of three segments. The upper segment is upward sloping and starts at the exchange rate level $\widehat{S}_1$, which is the level from which strategic default occurs. Larger values of $S_1$ have only a positive impact on output by lowering the period-two real interest rate. The second segment is downward sloping. This is the case where a currency depreciation lowers period-two wealth, which lowers period-three wealth and output. When $i_1^{*l} = i_0^{*l}$, this segment will be for $S_1$ between $P_1$ and $\widehat{S}_1$. When $S_1$ is below this point, which is the case where the currency appreciates compared to its expected level, the curve is upward sloping since the real interest effect dominates. Notice that without sunspots, the W curve is vertical. There is an impact of the exchange rate on future output only when there are deviations from ex post PPP, which in this case only occurs with sunspots.

The W curve shifts with changes in the lending rate in period one $i_1^{*l}$. For example, an increase in $i_1^{*l}$ shifts the curve downward, since it implies a higher cost of debt in period two and thus a lower output.

# 5 Sunspots Equilibria

In this section, we show under what conditions multiple equilibria including an equilibrium with currency crisis occur. Since prices cannot move within a period, an expectational shock has to be absorbed by the nominal exchange rate, which explains why it has output effects and can be self-confirming. We focus on the case where this expectation shift can only occur in the first period. To ensure this, we assume that the productivity parameter $\sigma_t$ in all but the first period is constant equal to $\sigma$, with $\sigma$ sufficiently high that there exists only one deterministic equilibrium at each period $t \geq 3$. Moreover, we shall assume that the central bank's policy consists in setting the nominal money supply $H_2^s$ in period 2, and the interest rate $i_t$ and the discount window rates $\theta_t$ in all periods.

For a given choice of $H_2^s$ and a given sequence of policy variables $(i_t, \theta_t)$, $t \geq 0$, we define an equilibrium as a sequence of allocations $w_t, y_t, l_t$, $t \geq 2$; a sequence of prices, exchange rates, and lending rates $P_t, S_t, i_t^{*l}, t \geq 1$; and a sequence of endogenous money supplies $H_t^s$, $t = 1$, $t \geq 3$, such that the following conditions hold (i) the transition equations for the firm net worth (10)-(12) given the paths of $P_t, S_t$ and $i_t^{*l}$ and the initial values $i_0^{*l}$, $w_1$; (ii) $y_t = \sigma_t(1+\mu)w_t$ and $l_t = \mu w_t$; (iii) the ex ante PPP condition $P_t = E(S_t)$ for all $t$; (iv) the interest parity condition (1), the money demand (3) and money market clearing (4) equation, and the banks zero-profit condition (6) for all $t$.

The recursive nature of the above system of equations implies that solving for the set of equilibria boils down to characterizing the equilibrium sequences $(y_{t+2}, S_t)$, $t \geq 1$, defined by the relationships "IPLM" and "W" between $S_t$ and $y_{t+2}$ for all $t$. For $t \geq 2$, we are taking the productivity parameter $\sigma_t = \sigma$ to be sufficiently large that no expectational equilibrium can occur. This, in turn, means that we can solve recursively for a unique deterministic sunspot equilibrium $(y_{t+2}, S_t)_{t \geq 2}$. This is given by

$$y_{t+2} = \sigma(1+\mu)w_{t+2}, \;\; w_{t+2} = \beta M_{t+1} w_{t+1} \text{ and } S_t = \frac{1+i^*}{1+i_t}.\frac{H_{t+1}^s}{y_{t+2}\frac{\gamma\mu}{\sigma(1+\mu)}(1-\frac{i_{t+1}}{2\lambda\theta_{t+1}})},$$

for $t \geq 2$, where $M_t = \beta(\alpha\sigma(1+\mu) - (1+i_t^{*l})\mu)$.

More interesting is the equilibrium analysis in period 1 where we allow for extrinsic uncertainty and expectational multiplicity. More specifically, we shall now derive sufficient conditions for the existence of non-degenerate sunspots equilibria $\{(y_3', S_1'), (y_3'', S_1''), q\}$ such that

(1) $q = pr(S_1 = S_1'')$ lies strictly between 0 and 1, and in fact must be allowed to be arbitrarily small;

(2) the pairs $(y_3', S_1')$ and $(y_3'', S_1'')$ satisfy

$$IPLM \quad S_1 = \frac{1+i^*}{1+i_1}.\frac{H_2^s}{y_3\frac{\gamma\mu}{\sigma(1+\mu)}(1-\frac{i_2}{2\lambda\theta_2})} = \frac{K}{y_3},$$

where $K$ is fixed by the choice of monetary policy $(H_2^s, i_2, \theta_2)$, and

$$W \qquad y_3 = \beta^2\sigma(1+\mu)(\alpha\sigma(1+\mu) - (1+i_1^{*l})\frac{P_1}{S_1}\mu)$$
$$\cdot \max\{\alpha\sigma_1(1+\mu) - (1+i_0^{*l})\frac{S_1}{P_1}\mu, \varphi\alpha\sigma_1(1+\mu)\}w_1,$$

where the first (resp. second) term in the curly bracket corresponds to the no-default equilibrium $(y_3', S_1')$ (resp. to the default equilibrium $(y_3'', S_1'')$).

(3) the initial price $P_1$ satisfies PPP, so that

$$P_1 = qS_1'' + (1-q)S_1'.$$

(4) [strategic] default occurs whenever the firm's default payoff—the second term in the above curly bracket for $y_3-$ is greater than its no-default payoff–the first term in the same bracket. Using the IPLM equation, this is equivalent to

$$(1-\varphi)\alpha\sigma_1(1+\mu) - (1+i_0^{*l})\frac{K}{P_1 y_3''}\mu \leq 0 \tag{14}$$

If we define $a = (1+i_0^{*l})\mu$ and $b = (1-\varphi)\alpha\sigma_1(1+\mu)$, (14) can be written as

$$P_1 \leq \frac{a}{b}S_1''. \tag{15}$$

Condition (3) imply that a sufficient condition for (15) to hold for arbitrarily small $q$ is

$$S_1' < \frac{a}{b}S_1'' \text{ and } \frac{a}{b} < 1.$$

Using again the IPLM equation, the above condition becomes

$$\frac{y_3'}{y_3''} > \frac{b}{a} \text{ and } \frac{a}{b} < 1.$$

We can reexpress $y_3'$ as

$$y_3' = \beta^2\sigma(1+\mu)w_1\left\{\Omega - \mu(1+\mu)\alpha\left[\sigma_1(1+i_1^{*l})\frac{P_1}{S_1'} + \sigma(1+i_0^{*l})\frac{S_1'}{P_1}\right]\right\},$$

where

$$\Omega = \alpha^2\sigma_1\sigma(1+\mu)^2 + \mu^2(1+i_0^{*l})(1+i_1^{*l});$$

Then, using PPP, the IPLM equation, and the fact that

$$y_3'' = \beta^2\sigma(1+\mu)\sigma_1(1+\mu)w_1\alpha\varphi\left(\alpha\sigma(1+\mu) - (1+i_1^{*l})\frac{P_1}{S_1''}\mu\right),$$

we can solve for $\chi = \frac{y_3'}{y_3''} = \frac{S_1''}{S_1'}$. The equation for $\chi$ is quadratic, and by solving it we find that when $q$ tends to zero, the ratio $\chi$ becomes approximately equal to

$$\chi = \frac{\alpha^2\sigma_1\sigma(1+\mu)^2 + \mu^2(1+i_0^{*l})(1+i_1^{*l}) - \mu(1+\mu)\alpha\left[\sigma_1(1+i_1^{*l}) + \sigma(1+i_0^{*l})\right]}{\alpha\varphi\sigma_1(1+\mu)\left(\alpha\sigma(1+\mu) - (1+i_1^{*l})\mu\right)}.$$

For a non-degenerate sunspot equilibrium with $q$ sufficiently small to exist, it suffices that

$$(C_1)\chi > \frac{b}{a} > 1.$$

In particular, $\varphi$ cannot be too large, otherwise $\frac{b}{a} < 1$, or $\mu$ cannot be too small otherwise $\chi < \frac{b}{a}$. This implies that countries with very low levels of financial development, i.e., with a very low $\mu$ and a high $\varphi$, are unlikely to experience expectational shocks and currency crises. Only those countries at an intermediate level of financial development, that is where $\mu$ is not too small or $\varphi$ is not too large but where firms are still credit-constrained, may experience currency crises. Finally, to the extent that a high value of $\sigma_1$ (and therefore of $b$) will also result in $\chi < \frac{b}{a}$, we can indeed rule out expectational shocks in periods $t \geq 2$ by assuming that for $t \geq 2$, firms' productivity $\sigma_t \equiv \sigma$ in all these periods is sufficiently high.

To complete our analysis we need to check that condition $(C_1)$ is consistent with condition $(C_0)$ (see footnote 21 above) guaranteeing that domestic entrepreneurs invest all their savings in their own projects. To see that these two conditions define a non-empty set of parameter values, assume condition $(C_0)$ and let $\varphi \to 0$ while keeping $\mu \leq 1$; then $\chi \to \infty$, whereas condition $(C_0)$ together with $\mu \leq 1$ implies that $\frac{b}{a} > 1$, so that $(C_1)$ ends up being also satisfied.

# 6 Policy Analysis

The appropriate monetary policy response to the recent crises has been a hotly debated question. Our framework, to the extent that it explicitly models the monetary side of the economy, appears to be well-suited for discussing these issues. Consider our monetary economy in period 1, and suppose that the sufficient conditions derived in the previous section for expectational shocks and currency crises to occur in period 1, are met. This implies that this economy can be described by Figure 3. The IPLM curve intersects the W curve at three points. Since the intersection in the middle is not a stable equilibrium, only the other two intersections are considered. They represent the crisis equilibrium at $(S_1'', y_3'')$ and the non-crisis equilibrium at $(S_1', y_3')$.

Can the monetary authorities react to the expectational shock in period 1 so as to move the IPLM and/or W curves in such a way that a currency crisis with $y = y_3''$ and a correspondingly high nominal exchange rate $S = S_1''$, can be avoided? More precisely, keeping future monetary policy $H_2^s$ and $(i_t, \theta_t)$ for all $t \geq 2$ fixed, can a crisis by avoided by choosing $(i_1, \theta_1)$ or $(H_1^s, \theta_1)$?[22] In particular suppose that in period 1 the monetary authorities use the supply of reserves $H_1^s$ and the discount window parameter $\theta_1$ to try and stabilize the economy, with the interest rate $i_1$ being endogenously determined by equation (5). Let us rewrite the equations for the IPLM and the W curve in period 1, namely[23]

$$IPLM \quad S_1 = \frac{1+i^*}{1+i_1} \cdot \frac{H_2^s}{y_3 \frac{\gamma\mu}{\sigma(1+\mu)}(1 - \frac{i_2}{2\lambda\theta_2})} = \frac{1+i^*}{1+i_1}\frac{\widetilde{K}}{y_3},$$

where $\widetilde{K}$ is fixed by future monetary policy and

$$W \qquad y_3 = \beta^2\sigma(1+\mu)(\alpha\sigma(1+\mu) - (1+i_1^{*l})\frac{P_1}{S_1}\mu) \cdot$$
$$\max\{\alpha\sigma_1(1+\mu) - (1+i_0^{*l})\frac{S_1}{P_1}\mu, \varphi\alpha\sigma_1(1+\mu)\}w.$$

[22] Again, we assume that future monetary policies in all periods $t \geq 2$ are fully anticipated by all agents in the economy, whereas monetary policy in period 1 is allowed to adjust in an unanticipated way to the expectational shock occurring during that period.

[23] As mentioned above, we take $i_2$ as given. However, one can show that the impact of monetary policy in period one is not significantly affected by having $i_2$ endogenous. Thus, suppose that instead of stabilizing $i_2$, the monetary authority targets money growth. Then second-period interest rate will depend on the entire dynamics of money supply. Let $z_t$ be the growth rate of the monetary base, such that $H_t^S = (1+z_t)H_{t-1}^S$.

For example to see what happens when $i_2$ is endogenized, suppose the monetary authority sets $z_3$ and let $i_2$ vary endogenously, but still keeping $i_t$ fixed for $t \geq 3$ (the reasoning can then be extended for any number of period, as long as the nominal interest rate is stabilized at some date before infinity).

The second-period interest rate is now determined by the equation $1+i_2 = (1+i^*)(1+\pi_3)$, which is derived from the interest rate parity condition $1+i_2 = (1+i^*)S_3/S_2$, using the fact that PPP holds after the first period. Then the inflation rate $\pi_3$ is determined by the money market equilibrium condition

$$1+\pi_3 = (1+z_3)\frac{h_2(y_3, i_2)}{h_3(y_4, i_3)}, \tag{16}$$

and $i_3$ is determined by the equation $1+i_3 = (1+i^*)(1+\pi_4)$. These equations jointly determine $i_2$ and $\pi_3$ as functions of $z_3$ for given values of $y_3$, $y_4$, and $\overline{\pi}_4$.

Note that $i_2$ depends on $\pi_3$ which in turn depends on $y_3$ and $y_4$. From (12) we see that $i_1$ has no direct impact on $y_4$ (for any fixed value of $y_3$). Thus, changing $i_1$ keeping $y_3$ fixed, leaves $\pi_3$ and therefore $i_2$ unaffected. This implies that movements in the IPLM curve are not affected by the endogeneity of $i_2$.

For a small probability of default $q$, the lending rate $i_1^{*l}$ is approximately equal to

$$1 + i_1^{*l} = (1 + i^*)[1 + \gamma \frac{i_1}{1 + i_1}(1 - \frac{i_1}{4\lambda\theta_1})]. \tag{17}$$

Consider first the effects of a reduction in the supply of reserves $H_1^s$ in period 1, keeping the discount window rate $\theta_1$ fixed. As already explained in Section 3, this unanticipated monetary change will be fully absorbed by an increase in the nominal risk-free interest rate $i_1$, according to equation (5). This interest rate increase rate will in turn shift the IPLM curve downward. If the W curve remained fixed, this would help stabilize the economy, in the sense of getting rid of the multiplicity of expectational equilibria. However, the W curve also shifts downward when $i_1$, and thereby also $i_1^{*l}$, increases. This in turn may prevent the monetary authority from avoiding multiple equilibria and a currency crisis. The reason is that the rise in interest rates may have a significant negative effect on future output, which in turn exerts a downward pressure on the currency value.

However $H_1^S$ is not the only instrument available for stabilization. We see in equation (17) that lowering $\theta_1$ lowers $i_1^{*l}$ for given interest rate $i_1$. This suggests the possibility of combining the increase in $i_1$ with a reduction in $\theta_1$, so as to keep the W curve unchanged while shifting the IPLM curve downward. Intuitively, in this model, there is a wedge between the rate paid to depositors ($i_1$) and the rate charged to borrowers ($i_1^{*l}$). Making it easier for banks to borrow from the central bank reduces this wedge, which in turn shifts the W curve up. The optimal policy in a crisis may therefore be to use the discount window to partially (or totally) offset the effect of the open market operations on the lending rate.

This argument, however, is not quite complete. We have not said anything about what influences the central bank's choice of $\theta$ when there is no crisis. In particular, it is not clear why $\theta$ should not be equal to zero to start with, given that a non-zero $\theta$ imposes an extra cost on borrowers. One way to justify an initial non-zero $\theta$ is to observe that in our model setting $\theta = 0$ causes the central bank to lose control of the money supply, since banks can generate as much credit as they want. It is not hard to think of reasons why the central bank may want to have some control on the volume of credit that is being generated. Introducing this motive into our model introduces a trade-off between the gains to the economy of a lower $\theta$ through its effect on investors, and the costs of reduced control over credit. The optimal monetary policy in 'normal' times balances these two objectives Facing a crisis shifts this trade-off, since the potential gains from lowering $\theta$ are much bigger (if it allows the economy to avoid the crisis). Therefore the central bank may find optimal to lower $\theta$ in a crisis.

The discussion so far assumes that the central bank cannot use a policy rule which makes future monetary policy a function of the exchange rate in the first period. If the central bank could commit to shrinking the money supply at the right rate in the event of a crisis, then, somewhat paradoxically, there would be no crisis. Essentially the shrinking of the money supply can guarantee that the price level in the second period becomes independent of the realization of the exchange rate in the first period, which effectively pins down the first period exchange rate. Therefore the sunspot cannot affect the exchange rate. It is however unclear that the central bank can commit to this type of policy rule. In particular, in the real world there is no such thing as a well defined second period, whereas in our model the second period is a discrete instant when the price level once again becomes free to adjust. In reality prices adjust at different times and the central bank probably does not know precisely when they are being adjusted.

# 7 Conclusion

This paper has concentrated on developing a full-fledged "third generation" model of currency crises. Whilst we have focused our attention on microfoundations, we have left out a number of interesting implications and extensions of this type of model. A first extension is to analyze the post-crisis dynamics of output. In the simple benchmark case considered in the above graphical analysis, there is a progressive recovery after a crisis, as firms build up their net worth. While the recovery is influenced by the policy at the time of the crisis, it is also influenced by monetary policy in the aftermath of the crisis. Thus, it would be of interest to examine the dynamics of output under various policy rules, such as inflation, monetary or exchange rate targeting. Longer lags of price stickiness and issues of credibility could also be introduced in the analysis.

The precise mechanics of exchange rate policy have also been left out from the analysis, but in Aghion, Bacchetta, and Banerjee (2001a) we show that assuming a fixed exchange rate does not affect the analysis in any substantial way. If the nominal exchange rate is fixed, the central bank has to change its money supply, e.g., through interventions in the foreign exchange market. If we assume that there is a lower limit to money supply, e.g., through a lower limit on international reserves as in Krugman (1979), the central bank will not be able to defend the currency when large shocks occur. Alternatively, the nominal exchange rate described in this paper can then be reinterpreted as the 'shadow' exchange rate typically used in the currency crisis literature. If the shadow exchange rate is depreciated enough, the fixed exchange rate has to be abandoned and a large depreciation occurs. In that case, the analysis derived from the IPLM-W graph in the above policy section, carries through at the 'good' equilibrium the fixed exchange rate is sustained, while at the 'crisis' equilibrium the fixed rate is abandoned. While the mechanism leading to a crisis is similar under a floating or fixed exchange rate, there may be differences between the two regimes that are not considered in the model. For example, a fixed exchange rate could lead to a stronger real appreciation which makes more likely that a large depreciation with default can happen.

This result stresses the central role played by corporate balance sheets and the potentially minor role played by exchange rate policies. Obviously, a deterioration of public finance can also contribute to a financial crisis (as argued in first and second generation models of currency crises), in particular through potential crowding-out effects on the balance sheet of private firms. The role of public finance and public debt and its interaction with the private sector are examined in some detail in Aghion, Bacchetta, and Banerjee (2001a). In particular, a public debt in foreign currency can increase the likelihood of a currency crisis as the public sector's loss from a devaluation may increase the interest payment and/or tax burden of firms.

A critical simplification has been to assume a constant credit multiplier $\mu$. This assumption simplifies the analysis and allows a better exposition of the main mechanisms at work. However, in a more general framework, the credit multiplier is influenced by other variables such as the real interest rate (see Aghion, Bacchetta, and Banerjee, 2001, for a model where $\mu$ depends negatively on the real interest rate). In this case, output may be more sensitive to monetary policy and the W curve is more likely to shift downward with a restrictive monetary policy. Thus, a currency crisis may be more difficult to avoid. Moreover, we should also try to understand better how the credit multiplier evolves during crises.

The paper has focused on the foreign currency exposure of *firms*, but the exposure of *banks* is also an important characteristic of recent financial crises. In the current setting, banks fully lend in foreign currency, but have enough assets not to go bankrupt after a depreciation. An interesting extension of the analysis is to incorporate explicitly currency exposure at the banking level. If currency depreciations entail significant losses for banks, the lending process may be disrupted (the credit-multiplier $\mu$ may be reduced) so that firms will again suffer from a currency depreciation. Introducing the possibility of a currency mismatch at both the bank and the firm levels, can provide new interesting insights.

Finally, we have focused attention on currency crises induced by expectational shocks, that is on the existence of non-degenerate sunspot equilibria. A natural extension is to introduce exogenous shocks, for example on firms' productivity. In particular, a (small) negative shock on productivity may have substantial effects on output and the nominal exchange rate if firms are highly indebted in foreign currency, to the extent that such a shock may result in the IPLM and W curves intersecting more than once.

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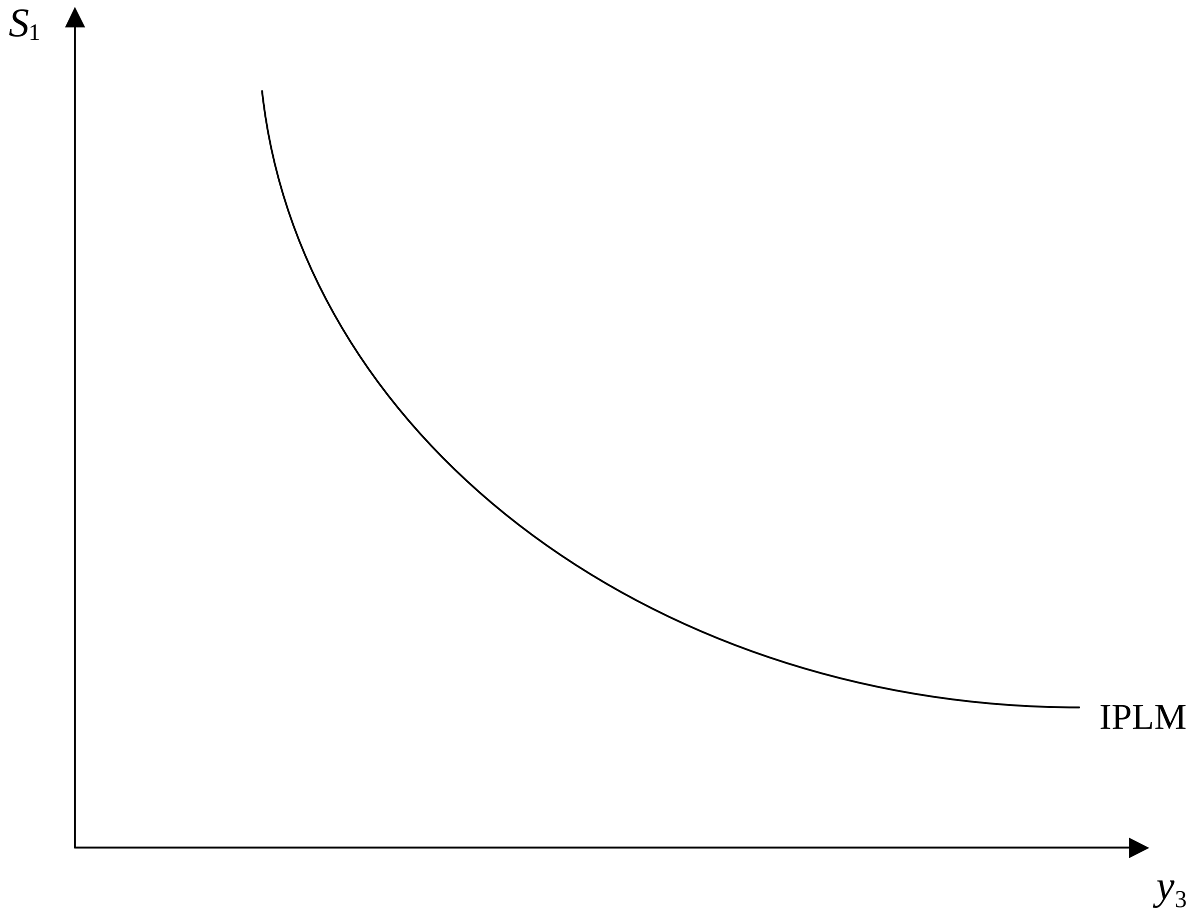


Figure 1

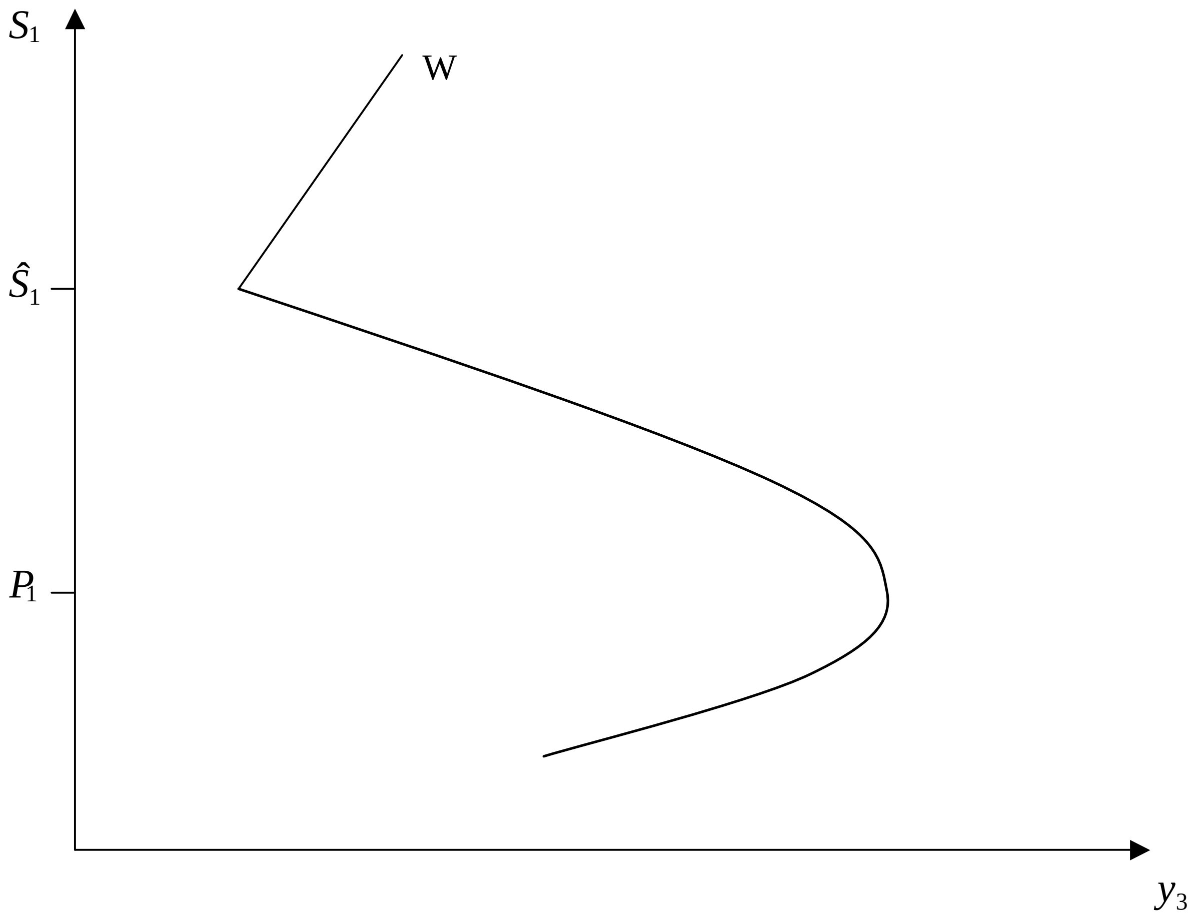


Figure 2

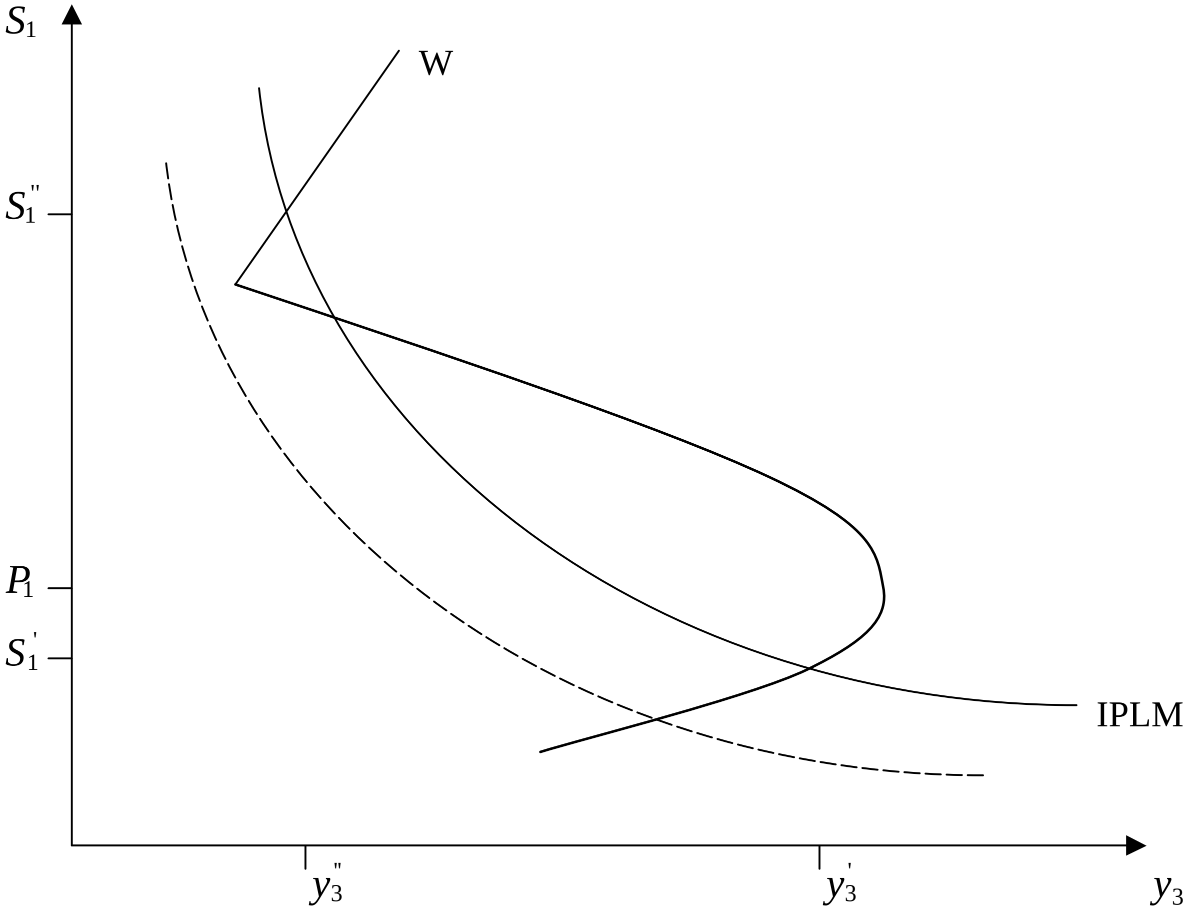


Figure 3