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A CORPORATE BALANCE-SHEET APPROACH TO CURRENCY CRISES

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Working Paper No. 01.05

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November 9, 2001

[1]We are grateful to Martin Eichenbaum, Michael Hutchinson, Sergio Rebelo, Ricardo Rovelli, and seminar participants at Harvard, Princeton, Bocconi, the IMF, the Konstanz Seminar, the CEPR-EPRU workshop on 'Analysis of International Capital Markets' in Copenhagen, and the Venice 2001 Summer Conference on Financial Crises. Bacchetta's work on this paper is part of a research network on 'The Analysis of International Capital Markets: Understanding Europe's role in the Global Economy,' funded by the European Commission under the Research Training Network Program (Contract No. HPRN-CT-1999-00067).

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 first show that with a positive likelihood of a currency crisis, firms may indeed find it optimal to borrow in foreign currency, following Chamon (2001). Second, we derive sufficient conditions for the existence of a sunspot equilibrium with currency crises. Third, we show that a reduction in the monetary base through restrictive open market operations is more likely to eliminate the possibility of currency crises if at the same time the central bank does not impose excessive constraints on short-term lending facilities.

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 (1998) 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, 2000a).

[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, 2000a, 2000b) feature the same basic story, as does the related paper by Krugman (1999b). Yet, our paper is an attempt to delve deeper into the story, with two main additions to the existing literature. First, the modeling of the credit market imperfection is being enriched so that both the volume of lending and the currency composition of debt become endogenous. This allows us to show the existence of an equilibrium where domestic entrepreneurs borrow in foreign currency, despite the fact that it makes the whole economy more vulnerable to currency crises. We thus depart from the view that it is the presence of government guarantees that leads countries to be overexposed to foreign currency risk and thereby to crises, with the implication that removing those guarantees would automatically solve the problem.[4] Our results suggest instead that overexposure may be built into the very nature of the contracting environment.

The second addition of this paper is to integrate 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 the role of monetary policy in a crisis depends crucially on how monetary policy affects firms' access to credit.[5] Integrating money and credit, in turn

[3] Most attempts to make sense of the 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 (1999), Caballero and Krishnamurty (2000). The key difference between these papers and the current paper is these are real models, whereas we stress the monetary elements in the story.

[4] See Krugman (1999a), Burnside, Eichenbaum and Rebelo (2000) and Schneider and Tornell (2000) for versions of this argument.

[5] 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 (2000a) we introduced such a real effect by directly assuming that a tighter monetary policy raises the real

generates useful predictions about the mix of monetary policy instruments. In particular, an important conclusion from our analysis is that it may be counterproductive for monetary authorities to be excessively tight with regard to both the monetary base (or the open market policy) and the lending facilities to banks (e.g., through the so-called discount window), if the objective is to stabilize the economy and avoid the occurrence of a currency crisis. Whenever a reduction of the monetary base appears to be the adequate policy to follow, it will be all the more appropriate if it is accompanied by a discount window policy which is not too tough.

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, Gilchrist and Natalucci (2000), Cespedes, Chang and Velasco (2000) and Christiano, Gust and Roldos (2000). 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 (2000b) 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. It also endogenizes the credit constraints and the currency composition of firms' debt. Deviations from Purchasing Power Parity (PPP) are caused by preset prices. 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

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.

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 various 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. 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. The model could be extended by introducing stronger competitiveness effects, for example with an exporting sector that has characteristics similar to the importing-competing. In that case, there would be a trade-off between a competitiveness effect and a foreign currency debt effect. Since the competitiveness effects are well understood, we do not incorporate this aspect in our model and focus on foreign currency debt.

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. Since prices cannot move within the entire period, this expectational shock will have to be absorbed by the nominal exchange rate, which explains why it has output effects and can be self-confirming. It is convenient to focus on the case where this expectation shift can only occur in the first period. To ensure this, we assume that the productivity in all but the first period is so high that there is only one possible equilibrium. We then allow the productivity in period 1 to vary. We then show that when the productivity is low enough, there will be 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. At the end of the period, manufacturing firms' earnings are determined. The productivity for the next period is also determined at this time. 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 nominal interest rate i_t on domestic bonds, which is influenced by the monetary policy set by the central bank and by the demand for reserves (h_t) from commercial banks. This in turn will affect the lending rate i_t^l charged by banks to firms in period $t+1$. The entrepreneur now decides whether or not to repay its debt from the previous period and then chooses the fraction β_t of his net earnings that he will save. With these savings w_t, firms 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 ω, in equilibrium we have:

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

Note also that sales net of wage payments are αy_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 σ sufficiently larger than σ_1 so that expectational shocks and multiple sunspot equilibria can occur in period 1, but there is 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, maximize their expected lifetime utility:[6]

$$\max \sum_{j=t}^{\infty} \beta^j E_t U(c_j)$$

$$s.t. \qquad w_{j+1} = M_j w_j - c_j$$

where c_j is an aggregate consumption index for manufactured goods and w_{j+1} is the entrepreneur's savings. If we assume that $U(c_t) = \ln c_t$, Appendix A shows that entrepreneurs consume a constant fraction $1 - \beta$ of their return, that is: $c_t = (1 - \beta)M_t w_t$ for all t. This implies that the dynamic evolution of entrepreneurs' wealth is given by:

$$w_{t+1} = \beta M_t w_t$$

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

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

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

$$\int_0^1 p_t(i) c_t(i) di = \Psi_t \tag{2}$$

where Ψ_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 $P_t = \left[\int_0^1 p_t(i)^{1-\nu} di \right]^{1/(1-\nu)}$.

[6] They could also derive utility from the homogenous commodity, but we assume, without loss of generality, that their optimal consumption 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.

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.[7] 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.

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) to 1, their price is S_t^e. The domestic producer has to set the same price to attract consumers (*ex ante* arbitrage) and sell them 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 ω denotes the foreign currency commodity price which we take to be constant and equal to ω. 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 ω.

[7] E.g., see Dornbusch (1988) for the difference between commodities and manufactured goods.

[8] This is the typical assumption made in the 'new open economy macroeconomics' literature. See for example Obstfeld and Rogoff (1995, 1996) and Bacchetta and van Wincoop (2000). Alternatively, in Butters (1977) or Prescott (1975) price-rigidity results from informational asymmetries and search costs.

[9] The strategy of pricing to market in domestic currency is taken as given. Bacchetta and van Wincoop (2001) provide conditions under which this strategy is optimal.

2.5 Credit

2.5.1 Interest Parity

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

$$1 + i_t = (1 + i^*)\frac{S^e_{t+1}}{S_t} \tag{3}$$

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 a model that is an extension of a model of ex post moral hazard in the credit market that was first developed by Aghion, Banerjee, and Piketty (1999).

We imagine a world where credit contracts are only partially enforceable. First, the borrower is protected by limited liability: he always retains at least a fraction φ 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 pay. This is the amount he can simply divert in a way that no one can find it afterwards.

Second, the borrower has the option of voluntary default 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 him in lieu of the interest payment.[11] 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 τ is lost. However the lender can still try to get his money back by putting effort into debt collection. Specifically, by incurring a nonmonetary

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

[11] This distinction between secured and non-secured loans will play an important role in Appendix B where we derive sufficient conditions under which it is (weakly) optimal for domestic firms to borrow entirely in foreign currency.

effort cost $l.C(\psi)$, where $C(\psi) = -c\ln(1-\psi)$ and l is the size of the loan, the lender can appropriate a fraction ψ of his due repayment (as long as the borrower has the money).

Finally, lenders do not have exclusive contracts. In particular, the first lender the borrower borrows from cannot automatically make the terms of the loan contract contingent on subsequent credit transactions. One reason this may be the case is that the second lender and the borrower could have the joint incentive to conceal the transaction, because they are both made better off by it. This implies that a first lender does not know the actual currency exposure of a firm. Moreover, the loans do not have predetermined seniority—when the borrower defaults, either voluntarily or involuntarily, the lenders bargain over the division of the costs of debt collection and the amount recovered from the borrower. We assume that lenders are repaid in proportion to the amount they are owed.

These three assumptions together determine the structure of the loan contract in equilibrium. This is what we investigate in the rest of this subsection.

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 his real interest rate obligation in that state of the world. He will not choose strategic default in period $t+1$ if and only if:

$$\alpha y_{t+1} - R_t l_{t+1} \geq \alpha(1-\tau)y_{t+1} - \psi R_t l_{t+1}, \quad (4)$$ [12]

or

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

Now, turning to the choice of the optimal monitoring policy ψ, the lender will choose ψ to maximize:

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

so his optimal choice of ψ is given by the first order condition:

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

[12] 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.

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 $y_{t+1} = \sigma_{t+1}(l_{t+1} + w_t)$. In this case, it is immediate that

$$\frac{\tau\alpha\sigma_{t+1}}{c - \tau\alpha\sigma_{t+1}} = \frac{l_{t+1}}{w_t} = \mu_t$$

Notice that in this case, μ_t depends only on σ_{t+1} and since σ_{t+1} is known when the loan is given, μ_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 has nothing is irrelevant). We now assume that c is so 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 $\mu_t w_t$.

Consider next the decision faced by a borrower who borrows an amount B_{t+1} and invests it in a pledgeable asset (say a government bond) that is then pledged against the loan. Suppose that in a particular state of the world, the income from the asset is z_{t+1} and the corresponding interest rate obligations are $R_t B_{t+1}$.If the borrower repays, his net income from this transaction will be $z_{t+1} - R_t l_{t+1}$. There is willful default if the borrower defaults despite z_{t+1} being greater than $R_t l_{t+1}$. Upon willful default, the lender seizes the whole income z_{t+1} (since it is pledged to him) and therefore the borrower ends up with zero. Willful default is therefore never a good option when the money is invested in an asset that is pledged against the loan. This in turn implies that there is no limit on the size B_{t+1} of a secured loan. This remark will play an important role in our analysis of the currency composition of domestic firms' loans.

Foreign versus Domestic Currency Borrowing The fact that the firms borrow in foreign currency will play 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 firms 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 (1999, 2000) develops models in which foreign currency borrowing serves as a signaling or as a commitment device. In this paper, foreign currency borrowing follows directly from the extrinsic exchange rate uncertainty together with the above assumptions on the set of feasible debt contracts, especially the assumption that the currency composition of a borrower's portfolio is not contractible. The argument is directly adapted from Chamon (2001)—we simply generalize his result to allow the firms to be credit constrainted.

Consider an initial situation where there is extrinsic uncertainty on the nominal exchange rate of the type described in section 3, with the nominal exchange rate, S_{t+1}, being either low (S'_{t+1} with probability $1 - q$) or so high (S''_{t+1} with small probability q) that a firm that has borrowed in foreign currency will have to default in that state. Assume, as above, that the firm prices in domestic goods. Then, given the assumption that an individual lender cannot observe the currency composition of a borrower's portfolio, one can show that for φ sufficiently large, in equilibrium it is (weakly) optimal for the firm to borrow entirely in foreign currency in order to benefit from limited liability in state S''_t. The proof is detailed in Appendix B, and relies on the following argument:

Consider a firm that borrows initially from a lender in domestic currency; since no individual lender can observe the currency composition of her borrower's portfolio, this firm has the possibility to expropriate its initial lender through the following scheme: use the initial loan in domestic currency to purchase government bonds which the firm then uses as a collateral for a second -secured- loan B in foreign currency. In case of default (which in equilibrium will happen in state S''_{t+1}) the non-diverted share $(1 - \varphi)$ of production revenues will be shared pro-rata between the two lenders (each of them being repaid in proportion to the amount she/he is owed[13]). The higher B, the more will the first lender be expropriated whenever the domestic firm defaults. On the other hand, being secured with a pledgeable collateral, the second lender will not charge an interest rate which fully incorporates the default premium, as the cost of default is essentially borne by the first lender whom we assumed to be unsecured. The firm therefore gains

[13] The amount the secured lender is owed, is net of the collateral seized in case of default.

in terms of expected payoffs by deviating from the strategy of borrowing only in domestic currency and choosing a high value of B. However it also takes on more risk in the process. It will prefer to deviate in cases where the increase in payoff dominates the increase in risk, which happens when φ is not too small (increasing φ increases the firm's default payoff). When it prefers to deviate in this way, the only possible equilibria have the domestic firm always defaulting in state S''_{t+1}, and getting the same expected utility as when it borrows entirely in foreign currency.[14]

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 and banks have a standard balance sheet structure. 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.[15] 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.[16]

We assume that banks' demand for reserves is linked to the supply of credit to the manufacturing sector: more specifically, suppose that with probability λ 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

[14] In subsequent periods, where there is no expectational shock and no default, domestic firms will be indifferent between borrowing in domestic or foreign currency.

[15] Notice the difference in timing notation between monetary and real-sector variables. Both h_{t-1} and l_t represent variables determined at the end of $t-1$ for period t. The difference in notation is imposed by the fact that we denote the nominal exchange rate at the end of period $t-1$ as S_{t-1}. Then, consistent with the interest paritiy condition, the nominal interest rate determined at the end of $t-1$, but valid for period t, is i_{t-1}. Consequently, we denote monetary variables determines at the end of $t-1$ by the $t-1$ subscript, even if they apply for period t.

[16] We abstract from liquidity needs from depositors so that they are indifferent between holding bank deposits or domestic bonds. There is also no transactions cost for banks to receive deposits. Alternatively, banks could also hold bonds and raise more deposits.

need is proportional to the amount l_t borrowed by the firm at the beginning of the period, γl_t. Thus, with each loan l_t a bank needs to provide liquidity γl_t to the borrowing firm with probability λ. If the lending bank does not fulfil this liquidity need, the firm cannot produce nor repay its outstanding debt.[17]

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 $\hat{\theta}_t$. 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:

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

We assume that this rate increases with the proportion of liquidity which is borrowed. For analytical convenience, we assume a linear relationship: $\hat{\theta}_t = \theta \cdot ((\gamma l_{t+1} - h_t)/\gamma l_{t+1})$, where θ is what we call the discount rate and can be changed by the central bank to modify monetary policy.[18] The optimal demand for reserves is then simply given by:[19]

$$h_t = \gamma l_{t+1}(1 - \frac{i_t}{2\lambda\theta}) = y_{t+1}\frac{1-\alpha}{\sigma_t}(1 - \frac{i_t}{2\lambda\theta}). \tag{5}$$

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:

$$\frac{H_t^S}{P_t} = h_t. \tag{6}$$

[17] The liquidity need is assumed constant throughout the analysis. An interesting extension would be to model this liquidity need and relate it to crises.

[18] An alternative interpretation of the parameter θ 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 δ of a bank's liquidity need γl_t, where δ 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 θ.

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

When changes in monetary policy, that is in either H_t^S or θ, are anticipated, then the equilibrium price P_t will fully adjust to such changes. However, when changes in monetary policy are unanticipated, the monetary change will be fully absorbed by the nominal interest rate, which from the above equation (10), can be expressed as:

$$i_t = 2\lambda\theta(1 - \frac{H_t^S}{\gamma P_t l_{t+1}}) \tag{7}$$

Thus the central bank can increase the nominal risk-free interest rate in two ways: either by decreasing the monetary base H_t^S or by increasing the discount window rate θ (or equivalently by tightening its limits to refinancing).

3.2 The Cost of Lending

Banks lend to manufacturing firms at a nominal interest rate i_t^{*l} in foreign currency units. In general we will need to allow for the possibility of default: Assume 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. Its 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 which we denote by $(1 + i_{ct})P_t l_{t+1}$. 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

$$(1 + i_{ct})P_t l_{t+1} = (1 + i_t)P_t l_{t+1} + i_t P_t h_t + \lambda P_t(\gamma l_{t+1} - h_t)\theta_t.$$

Using these two equations and letting π_t and r_t denote the inflation rate and the real interest rate at date t, we get:[20]

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

[20]Using the fact that the inflation rate π_t is determined by the following equation, in which z_t denotes the growth rate of reserves supply at date t, which itself follows directly from (6): $1 + \pi_t = (1 + z_t)\frac{h(l_t, i_{t-1})}{h(l_{t+1}, i_t)}$.

By using (5), interest parity and the definition of θ_t, we then find:

$$(1+i_t^{*l}) = \frac{1+i^*}{1-q_t} \quad 1 - q_t(1-\varphi)\frac{\sigma(1+\mu)}{(1+r_t)\mu} + \gamma\frac{i_t}{1+i_t}(1-\frac{i_t}{4\lambda\theta})$$

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 θ. As we shall see in Section 6 below, tightening the money supply by increasing θ and by reducing H_t^s, not only have different effects on the overall equilibrium outcome, but also may end up being mutually offsetting.

3.3 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 (11), we obtain the following "IPLM" relationship between S_1 and y_3 :

$$S_1 = \frac{1+i^*}{1+i_1}.\frac{H^s}{y_3\frac{1-\alpha}{\sigma}(1-\frac{i_2}{2\lambda\theta})}. \tag{8}$$

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 φ of a firm's output cannot be appropriated by its lenders,[21] and allowing for strategic default, nominal profits are:

$$\Pi_t = \max\{\alpha P_t y_t - (1 + i_{t-1}^{*l})\frac{S_t}{S_{t-1}} P_{t-1} l_t, \alpha\varphi P_t y_t\}, \tag{9}$$

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 $\varphi\alpha P_t y_t$.[22] 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'' correspondingly high.

>From the optimal savings behavior of entrepreneurs, total net wealth available for the next production period $t + 1$ is then given by:

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

If we focus on a potential crisis occurring at time 1, we can look at entrepreneurs' wealth at time 2:

$$w_2 = \beta \max\{\alpha\sigma_1(1 + \mu) - (1 + i_0^{*l})\frac{S_1}{P_1}\mu, \alpha\varphi\sigma_1(1 + \mu)\}w_1. \tag{10}$$

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

[22] 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.

A currency depreciation clearly has a negative impact on w_2 as it increases the debt burden. 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 throughout these periods 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).

4.2 The W curve

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

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

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 $\hat{S}_1$, 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 $\hat{S}_1$. 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 real interest 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 occur. We characterize the set of equilibria (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. The path of policy variables, H_t and i_t, is also assumed given. This, in turn, means that we can solve recursively for a unique deterministic sunspot equilibrium (y_{t+2}, S_t). This is given by:

$$y_{t+2} = \sigma(1+\mu)w_{t+2},\ w_{t+2} = Mw_{t+1} \text{ and } S_t = \frac{1+i^*}{1+i}.\frac{H_{t+1}^s}{y_{t+2}\frac{\gamma\mu}{\sigma(1+\mu)}(1-\frac{i}{2\lambda\theta})},$$

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

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:

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

and:

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

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

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

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

$$R > \frac{b}{a} > 1.$$

In particular, φ cannot be too large, otherwise $\frac{b}{a} < 1$, and μ cannot be too small otherwise $R < \frac{b}{a}$. For example, at $\mu = 0$, $R = 1/\varphi$ and b/a goes to infinity. This implies that countries with very low levels of financial development as measured by μ and/or φ are unlikely to experience expectational shocks and currency crises. Only those countries at an intermediate level of financial development, that is where μ is not too small (or φ is not to large) but where firms are still credit-constrained, may experience currency crises. Finally, to the extent that a high value of σ_1 (and therefore of b) will also result in $R < \frac{b}{a}$, 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.

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 do anything that would 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? In the context of our model, the monetary authorities can use two instruments at time one to try and stabilize the economy: namely, the supply of reserves H_1^s and the discount window parameter θ_1.[23] Let us rewrite the equations for the IPLM and the W curve in period 1, namely:[24]

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

and

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

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

$$1 + i_1^{*l} = (1+i^*)[1 + \gamma\frac{i_1}{1+i_1}(1 - \frac{i_1}{4\lambda\theta})]. \tag{16}$$

Consider first the effects of a reduction in the supply of reserves H^s in period 1. As shown in section 3, this unanticipated monetary change will be fully absorbed by the nominal risk-free interest rate i_1, where: $i_1 = 2\lambda\theta(1 - \frac{H^S}{\gamma P_1 l_1})$. Now, to the extent that it increases i_1, such a reduction in the monetary base will shift the IPLM curve downward. For a given W curve, this will 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^{*l} increases, and thus when i_1 increases. Thus it may not be possible to avoid a crisis. The reason is that the rise in interest rates may have a significant negative effect on future output, which puts a downward pressure on the currency value.

[23] Future policies, such as H_2^S and θ_2 can also be changed, but the impact of these changes is left as an exercise to the reader.

[24] As mentioned above, we take i_2 as given. However, we show in Appendix C that the impact of monetary policy in period one is not significantly affected by having i_2 endogenous.

Looking at the expression for the lending rate i_1^{*l}, we see that the smaller θ, the less the W curve will shift downward when i_1 increases. Thus, a restrictive open market operation (a reduction in the monetary base) that increases i_1 is less effective with a tight discount window policy.[25]

This analysis shows that short-term lending facilities and open market operations have different implications, which implies that the central bank has two instruments for monetary policy. It is then easy to see that the best strategy to avoid multiple equilibrium is to have a restrictive open market operation with an expansionary discount policy. This would shift the IPLM curve to the left and limit the shift in the W curve.

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 (2001) 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.

[25] It is even possible that the W curve shifts more than the IPLM curve for large values of θ.

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 (2001). 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 μ. 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 μ 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 do not 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 μ 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.

8 Appendix A: Entrepreneurs' savings decisions

An entrepreneur will choose his optimal consumption based on:

$$\begin{aligned} & \max \sum_{j=t}^{\infty} \beta^j E_t \ln(c_{e,j}) \\ s.t. \qquad c_{e,j} &= M_j w_j - w_{j+1} \end{aligned}$$

The first order condition gives:

$$\frac{1}{c_{e,t}} = \beta E_t \left[\frac{M_{t+1}}{c_{e,t+1}} \right] \tag{17}$$

Assuming that the solution is of the form

$$c_{e,t} = \xi M_t w_t \tag{18}$$

and substituting it into (17), we obtain:

$$\frac{1}{\xi M_t w_t} = \beta E_t \left[\frac{1}{\xi w_{t+1}} \right] = \frac{\beta}{\xi w_{t+1}}$$

which in turn yields:

$$w_{t+1} = \beta M_t w_t$$

Since $c_{e,t} = M_t w_t - w_{t+1}$, this is consistent with (18) when $\xi = 1 - \beta$.

9 Appendix B: Foreign versus Domestic Currency Borrowing

This Appendix shows that when the currency composition of debt cannot be observed, there exist conditions under which it is weakly optimal for a domestic firm to borrow entirely in foreign currency from a single borrower. The argument is directly adapted from Chamon (2001)—we simply generalize his result to allow the firms to be credit constrainted.

Consider an initial situation where there is extrinsic uncertainty on the nominal exchange rate of the type described in Section 3, with the nominal exchange rate, S_{t+1}, being either low (S'_{t+1} with probability $1-q$) or very high (S''_{t+1} with small probability q). The key assumption is that the exchange rate depreciation, when it happens, is large enough that a manufacturing firm that borrows in foreign currency but prices in domestic currency, will prefer to default on the loan, that is:

$$P_{t+1}\sigma w_t(1+\mu_t) - (1+i_t^{*l})S'_{t+1}w_t\mu_t \quad > \quad \varphi P_{t+1}\sigma w_t(1+\mu_t) \tag{19}$$

$$P_{t+1}\sigma w_t(1+\mu_t) - (1+i_t^{*l})S''_{t+1}w_t\mu_t \quad < \quad \varphi P_{t+1}\sigma w_t(1+\mu_t). \tag{20}$$

Here i_t^{*l} is the equilibrium foreign currency interest rate, which must satisfy the zero profit condition.[26]

$$\frac{(1-q)(1+i_t^{*l})S'_{t+1}w_t\mu_t + q(1-\varphi)P_{t+1}\sigma w_t(1+\mu_t)}{P_t} = (1+i_{ct})w_t\mu_t, \tag{21}$$

where i_{ct} is the lending cost at date t.

We are interested in whether, given these expectations about the exchange rate, it can be optimal for a firm to borrow in foreign currency. It is obvious that in this scenario the socially efficient outcome has the firm borrowing only in the domestic currency and thereby being fully insured against the exchange rate risk (the lenders who are risk neutral should insure the firm which has log-preferences and therefore is risk averse). However, it will turn out that because of the unobservability of the currency composition of debt, borrowing exclusively in the domestic currency is not necessarily an equilibrium outcome.

Let us reason by contradiction and assume that borrowing entirely in domestic currency is an equilibrium. More specifically, consider a domestic firm

[26] The implicit assumption here and throughout the paper is that investors are fully diversified and therefore risk-neutral.

that has contracted a domestic currency loan of $P_t w_t \mu_t$ invested in production. If it sticks to that loan and does not borrow from any other lender, the firm can expect domestic currency earnings of $P_{t+1} y_{t+1} = P_{t+1} \sigma w_t (1 + \mu_t)$ and it faces an expected debt repayment obligation of $P_t(1 + i_{ct})\mu_t w_t = L^D_{t+1}$ in domestic currency. However, as in Chamon (2001), the firm may actually contemplate a deviation from this one-domestic-loan strategy and borrow again, this time in foreign currency. Suppose it borrows an additional amount B in foreign currency and uses it to buy BS_t units of domestic currency government debt (which pays an interest rate i_t) that it then pledges to the second lender. As already mentioned in a previous section, the fact that the loan is secured by a pledgeable asset means that there is no limit to the amount that can be borrowed: B can be as large as the borrower wants it to be. Moreover, since this loan is not a production loan it does not generate any demand for liquidity. So the cost of the second loan is just i_t.

Note that since this second loan is repayable in foreign currency but is invested in domestic currency bonds, taking this route exposes the firm to exchange rate risk but the firm's expected earnings are unchanged. In particular, it is easily checked that the firm loses money in state S''_{t+1} by taking this route and makes money in state S'_{t+1}. For B small it will nevertheless be able to repay both loans in both states of the world. Therefore, a small increase in B starting from zero makes the firm worse off—it has the same expected earnings but more risk. Therefore it cannot be optimal to ever choose B in this range.

Consider however what happens when the chosen value of B is so large that the firm has to default in state S''_{t+1}. In this case the interest rate on this second loan (once again assuming zero profit in lending), i'_t, will have to satisfy:

$$\begin{aligned} BS_t(1+i_t) &= (1-q)B(1+i'_t)S'_{t+1} \\ &\quad + q[BS_t(1+i_t) + (\frac{B(1+i'_t)S''_{t+1} - BS_t(1+i_t)}{B(1+i'_t)S''_{t+1} - BS_t(1+i_t) + L^D_{t+1}})D''_{t+1}], \end{aligned}$$

where

$$D''_{t+1} = (1-\varphi)\sigma w_t(1+\mu_t)P_{t+1}.$$

This follows from the fact that in case of default, the second lender keeps the asset that is pledged to him, and in addition, gets a share of the part of the borrower's production output that has not been diverted. The share each lender gets is in turn proportional to the net firm's repayment obligation toward that lender. The above equation can be reexpressed as:

$$B(1+i^l_t)S'_{t+1} = BS_t(1+i_t) - \frac{q}{1-q}\left(\frac{B(1+i^l_t)S''_{t+1} - BS_t(1+i_t)}{B(1+i^l_t)S''_{t+1} - BS_t(1+i_t) + L^D_{t+1}}\right)D''_{t+1}.$$

The latter equation shows clearly that as B goes up the second lender's share of the production revenue D''_{t+1} goes up, and therefore the lower is i^l_t. Since the increase in B being mooted is a deviation from a putative equilibrium, the first lender cannot observe the change in B, and therefore this increase in B must leave the interest rate charged by the first lender unchanged. Therefore, once B is so large that default in state S''_{t+1} is inevitable, any further increase in B makes the borrower better off. Given that the borrower can borrow as much as he wants (this is where the fact that the second loan is secured matters), his optimal choice, conditional on choosing $B > 0$, is to choose B as large as possible. It is easily checked that when B becomes very large, the interest rate charged by the second lender approaches i_2, where

$$BS_t(1+i_t) = BS'_{t+1}(1+i_2) + \frac{q}{1-q}(1-\varphi)\sigma w_t(1+\mu_t)P_{t+1}.$$

The borrower's utility if he deviates from this option will be:

$$\begin{aligned} U^1 &= (1-q)\ln(\sigma w_t(1+\mu_t) + B(1+i_t)\frac{S_t}{P_{t+1}} - \frac{B(1+i_2)S'_{t+1}}{P_{t+1}} \\ &\quad - \frac{\mu_t w_t(1+i^l_t)P_t}{P_{t+1}}) + q\ln(\varphi\sigma w_t(1+\mu_t)) \\ &= (1-q)\ln(\sigma w_t(1+\mu_t)) - \frac{P_t}{P_{t+1}}\mu_t w_t(1+i_{ct}) + \frac{q}{1-q}(1-\varphi)\sigma w_t(1+\mu_t)) \\ &\quad + q\ln(\varphi\sigma w_t(1+\mu_t)). \end{aligned}$$

In writing the last expression we make use of the fact that i^l_t is equal to i_{ct}, which in turn follows from the fact that we started by assuming that borrowing entirely in domestic currency, with domestic loans being consequently riskless, was an equilibrium. The question of whether there is an equilibrium with only domestic currency borrowing therefore boils down to how the expression above compares with the utility from just borrowing in domestic currency, namely:

$$U = \ln(\sigma w_t(1+\mu_t) - (1+i_{ct})w_t\mu_t\frac{P_t}{P_{t+1}})$$

While the expected income generated by the above multiple loans strategy is higher than that generated by a single domestic currency loan, the risk is also higher. Now, one can verify that for φ sufficiently large but not so large as making default occur in all states of nature, e.g., for φ less than but close to $(1 - \frac{(1+i_t^{*l})S'_{t+1}\mu}{P_{t+1}\sigma(1+\mu)})$, U^1 will be greater than U, so that borrowing only in domestic currency will not be an equilibrium.

The final step in the argument is to note that in any equilibrium where the domestic firm borrows first in domestic currency and then chooses B to be arbitrarily large, its expected utility becomes approximately equal to:

$$
\begin{aligned}
U^2 &= (1-q)\ln(\sigma w_t(1+\mu_t)) - \frac{P_t}{P_{t+1}}\mu_t w_t(1+i_t^l) + \frac{q}{1-q}(1-\varphi)\sigma w_t(1+\mu_t)) \\
&\quad + q\ln(\varphi\sigma w_t(1+\mu_t)) \\
&= (1-q)\ln(\sigma w_t(1+\mu_t)) - \frac{1}{1-q}\frac{P_t}{P_{t+1}}\mu_t w_t(1+i_{ct}) + \frac{q}{1-q}(1-\varphi)\sigma w_t(1+\mu_t)) \\
&\quad + q\ln(\varphi\sigma w_t(1+\mu_t))
\end{aligned}
$$

The last step uses the fact that in this equilibrium the first lender only expects to be paid in state S'_{t+1} and therefore $1 + i_t^l = \frac{1+i_{ct}}{1-q}$.

Had the borrower borrowed instead entirely in the foreign currency, the borrower's expected utility would be:

$$
\begin{aligned}
U^3 &= (1-q)\ln(\sigma w_t(1+\mu_t) - \frac{\mu_t w_t(1+i_t^{*l})S'_{t+1}}{P_{t+1}}) \\
&\quad + q\ln(\varphi\sigma w_t(1+\mu_t)),
\end{aligned}
$$

where i_t^{*l} satisfies:

$$
(1+i_{ct})P_t\mu_t w_t = (1-q)\mu_t w_t(1+i_t^{*l})S'_{t+1} + q(1-\varphi)P_{t+1}\sigma w_t(1+\mu_t),
$$

so that:

$$
\begin{aligned}
U^3 &= (1-q)\ln(\sigma w_t(1+\mu_t) - \frac{1}{1-q}\frac{P_t}{P_{t+1}}\mu_t w_t(1+i_{ct}) + \frac{q}{1-q}(1-\varphi)\sigma w_t(1+\mu_t)) \\
&\quad + q\ln(\varphi\sigma w_t(1+\mu_t))
\end{aligned}
$$

But this is exactly the expression for U^2. In other words, the borrower does just as well by borrowing entirely from a single lender in the foreign currency. Therefore borrowing entirely in foreign currency is an equilibrium whenever $U < U^1$.

10 Appendix C: Endogenous Future Interest Rates

Here we show that the impact of monetary policy in period 1 is not affected by the future path of monetary policy (assuming it is credible). In the main text, it is assumed that the central bank stabilizes i_2. If the monetary authority targets money growth, the 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 $H_t^S = (1 + z_t)H_{t-1}^S$. To see what happens when i_2 is endogenized, we analyze a simple extension of the basic model where we set 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 π_3 is determined by the money market equilibrium condition

$$1 + \pi_3 = (1 + z_3)\frac{h_2(y_3, i_2)}{h_3(y_4, i_3)}, \tag{22}$$

and i_3 is determined by the equation $1+i_3 = (1+i^*)(1+\pi_4)$. These equations jointly determine i_2 and π_3 as functions of z_3 for given values of y_3, y_4, and $\overline{\pi}_4$.

Note that i_2 depends on π_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 π_3 and therefore i_2 unaffected. This implies that movements in the IPLM curve are not affected by the endogeneity of i_2.

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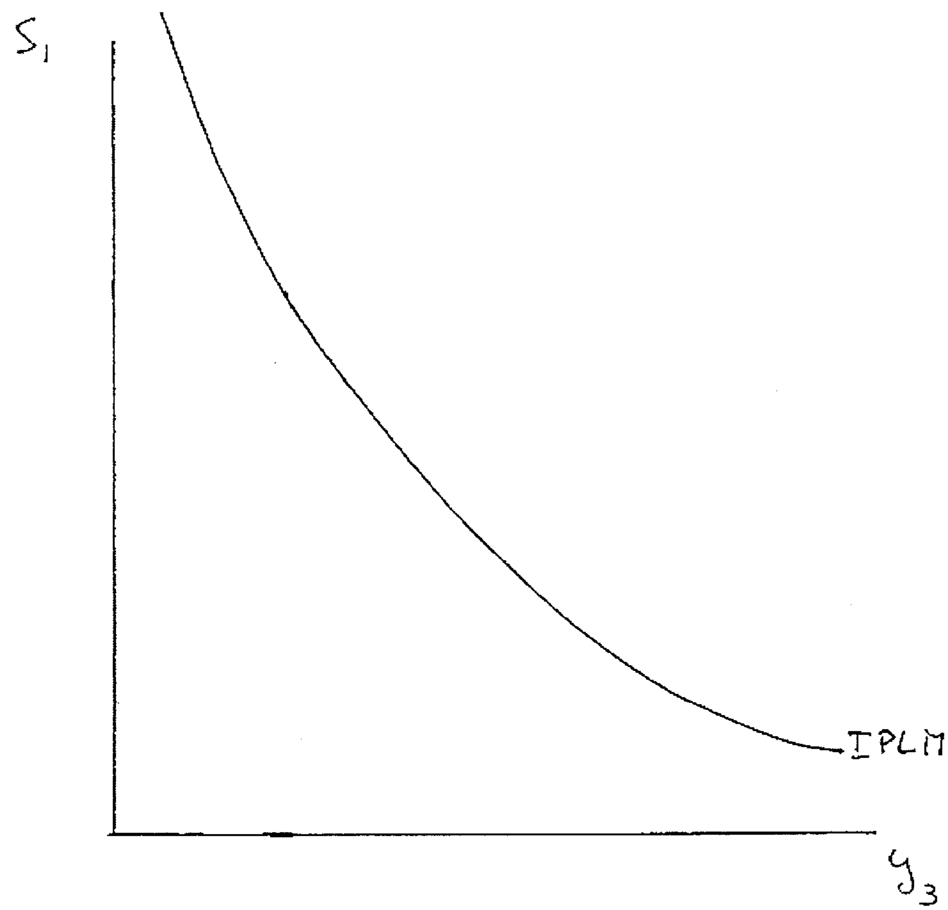

Figure 1

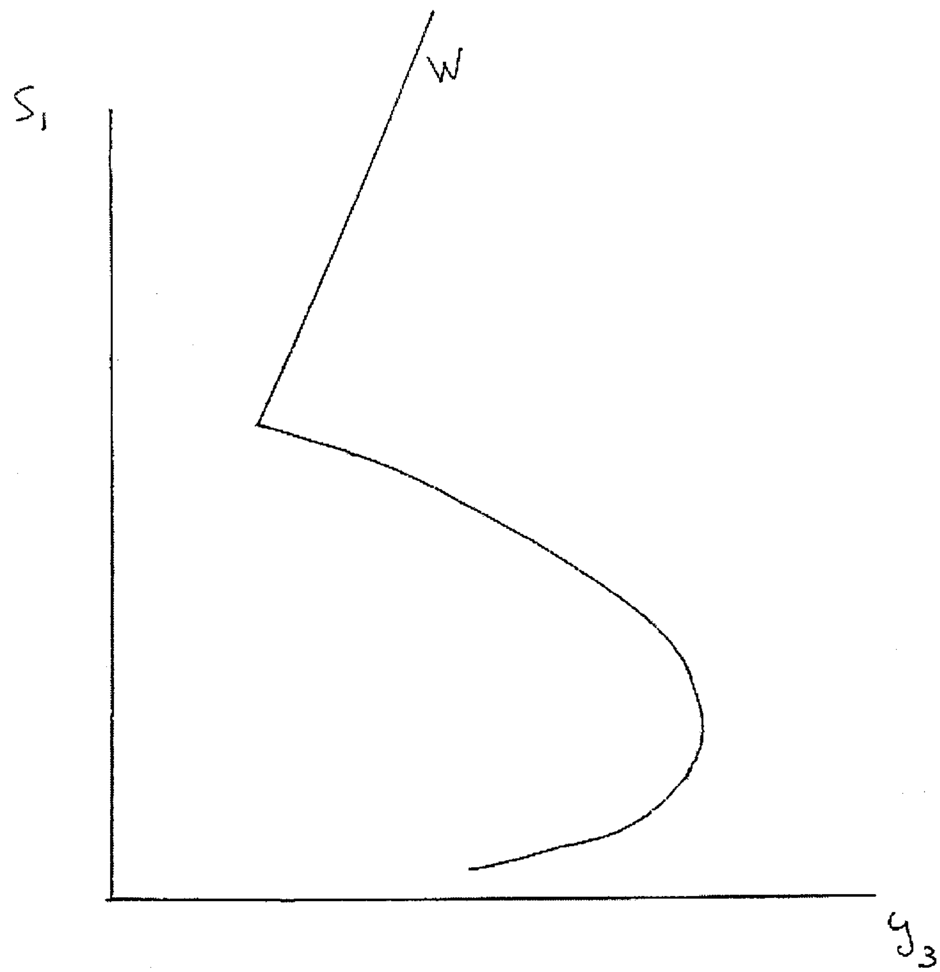

Figure 2

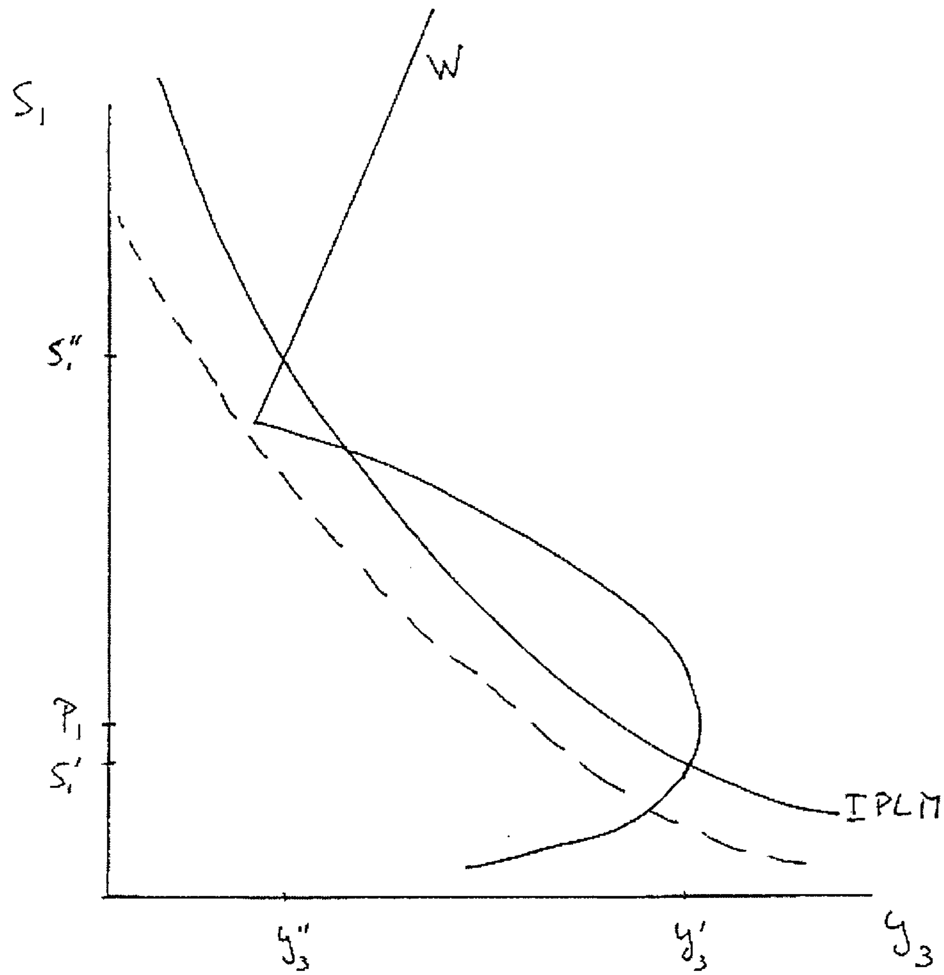

Figure 3