

# **The International Lender of Last Resort: How Large Is Large Enough?**

Olivier Jeanne  
IMF Research Department and CEPR

Charles Wyplosz  
Graduate Institute of International Studies and CEPR

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### **Abstract**

This paper considers the size of international lending-in-last-resort that is required to prevent self-fulfilling banking crises in emerging economies. We present a model of an open economy where banks exhibit both a maturity and a currency mismatch between their assets and their liabilities. While self-fulfilling bank runs can in principle be prevented by international lending-of last-resort, the required amount of lending is increased by the fact that some of it ends up siphoned out of the country by currency speculation—instead of going to the agents faced with a run on their foreign currency liabilities. We present evidence from recent crises supporting the view that international financial assistance might be swamped by currency speculation.

**Key Words:** lender of last resort, bank runs, banking crises, multiple equilibria, deposit insurance, Asian crisis, International Monetary Fund.

*JEL Classification System:* F32, F33, F34, G21.

## 1. Introduction

The Asian crises have triggered a debate on how new rules and institutions could increase the resilience of the international monetary system. Among many proposals, it has been suggested that an international lender of last resort would be useful addition. One idea is to set up an international central bank which would issue a global currency (Garten, 1998). Other ideas, at the more realistic end of the spectrum, start from the observation that crisis lending by the international community—and in particular by the IMF— has already evolved toward *de facto* lending in last resort since the Mexican bailout (Fischer, 1999). In particular the recent adoption of Contingent Credit Lines by the IMF may be seen as an attempt at formalizing this trend.

The idea that an international lender of last resort could and should become the linchpin of the global financial architecture has been criticized on different grounds. It has been noted, first, that an international lender of last resort would worsen the moral hazard problem which, some argue, is one of the main causes of fragility of the international financial system (Meltzer, 1998). Another argument is that while a true international lender of last resort might be desirable in theory, it has no chance of being instituted in practice because the institutional changes involved go well beyond what the international community is ready to accept (Eichengreen, 1999). Some further claim that an international lender of last resort cannot function effectively unless it can issue an indefinite amount of its own currency (Capie, 1998), while others argue that the lender of last resort would need an amount of hard currencies which, though finite, is unrealistically large (Eichengreen, 1999; Rogoff, 1999).

The debate suggests that the notion of an international lender of last resort is not well-understood. Questions range from the nature of crises to the arrangements required for the lender of last resort to operate. This paper proposes a formal framework which may help shed light on several of these issues.<sup>1</sup> Special attention is paid to the problems that arise specifically from the international dimension of lending-in-last-resort, in particular those related to currency mismatches in the balance sheets of banks. One theme of this paper is that because of the combination of currency mismatches and adjustable exchange rates, the task of the international lender of last resort cannot be thought of as a simple transposition from the closed economy context. In particular, the rules proposed by Bagehot at the beginning of the Classical gold standard—and often invoked in the current debates—provide incomplete guidance as to the optimal lending-in-last-resort policies in the modern international financial environment.

We consider an open economy where banks exhibit both a maturity and a currency mismatch between their assets and their liabilities. While bank regulation typically disallows currency mismatches, one of the lessons from the recent crises is that they do occur and can be

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<sup>1</sup> Goodhart and Huang (2000) present another model of international lending-in-last-resort, which highlights, as we do, the importance of exchange rates.

sizeable. Even when the banks themselves avoid currency mismatches, firms which are their customers may carry such a risk on their own books. If many large firms fail simultaneously, so will their banks, especially as maturity mismatch is a key function of the banking system. The combination of currency and maturity mismatches makes banks to self-fulfilling international financial crises. An international lender of last resort (LOLR) can in principle remove bad equilibria. We scrutinize the size of LOLR interventions that are required to that effect. We then discuss the quantitative implications of our model using data from recent crises.

A common approach to the question of the required size of international financial assistance is to look at the liquidity gap in the aggregate balance sheet of countries, i.e., the difference between the country's foreign-currency denominated liabilities that come to maturity over a given time period (say, 6 or 12 months) and the country's liquid foreign-currency-denominated assets, most notably the foreign exchange reserves.<sup>2</sup> An estimate of liquidity gaps is shown in Figure 1 for selected crisis countries from Asia and Latin America that will be studied in more detail later. The period includes crisis years in Asia and Mexico. In Asia, the liquidity gap has been increasing over the years leading to the 1997 crisis, although Malaysia never had any gap. The precipitous dip after the crisis (data is end-of year) reflects the depletion of foreign exchange reserves. Interestingly, it is of the same order of magnitude as the rescue packages made available by the IMF and other official lenders: \$ 40 bil. for Indonesia, \$ 57 bil. for Korea, \$ 17.2 bil. for Thailand. This is also the case of Mexico which was promised \$ 40 bil. in 1995.

[Insert Figure 1]

We argue in this paper that an approach entirely based on countries' pre-crisis balance sheets is at best partial, and may be seriously misleading. The demand for foreign exchange reserves, in a crisis, is not limited to the liquidity gap in the balance sheet: it may also include a currency speculation component if investors take short positions in the domestic currency. The currency speculation component, in our model, may be much larger than the liquidity gap, and tends to infinity when investors are risk neutral.

This problem arises, as we argue below, as the joint result of two factors: (i) the currency mismatch in the balance sheet of the private sector, and (ii) the exchange rate pressure which arises endogenously in banking crises. In the absence of currency mismatch there would be no need for an *international* LOLR—the domestic monetary authorities could provide all the required liquidity by using their reserves and by creating domestic currency. In the presence of a currency mismatch, however, the Bagehot rule of lending only to solvent but illiquid

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<sup>2</sup> This is the approach taken by Alan Greenspan in a recent speech, in which he argues that emerging economies should keep enough reserves to finance their liquidity gap over the following year (Bussière and Mulder, 1999).

institutions on good collateral becomes ambiguous. The solvency of banks depends on the level of the exchange rate, which is itself endogenous to the banking crisis. The “bad” equilibrium is not removed if the LOLR lends only to banks that are solvent on the basis of the prevailing exchange rate, since in the bad equilibrium banks are *made* insolvent by the depreciation of the domestic currency—the same banks would be solvent in the good equilibrium with a less depreciated domestic currency.<sup>3</sup> Hence in order to effectively remove bad equilibria the LOLR must maintain the dollar price of domestic assets close to the level that would prevail in the good equilibrium. This constrains monetary policy and generates a speculative demand for foreign exchange reserves which might exceed the liquidity gap by a considerable margin.

The logic of our argument does not rely on the existence of a fixed currency peg. Whether the domestic currency is fixed or floating, the only way to keep domestic agents solvent is by allowing them to exchange their domestic currency-denominated assets against foreign currency *at a price that is close to the good equilibrium level*. This task becomes impossible if speculative pressure against the domestic currency creates a lose-lose situation with the domestic country facing the choice between currency depreciation and high interest rates. A floating exchange rate regime allows the domestic monetary authorities to set lower interest rates, but the associated exchange rate depreciation is no less destabilizing for the domestic financial sector—when there is a currency mismatch—than high interest rates.

The crucial issue, we argue, is not the exchange rate regime but the articulation between international lending-in-last-resort and domestic financial supervision and safety nets. If the domestic monetary authorities use the reserves lent by the international lender of last resort for foreign exchange interventions, *even unsterilized ones*, most of the reserves are likely to end up siphoned out of the country by currency speculation –instead of going to the domestic agents who most need them, those who are faced with a run on their foreign currency liabilities. There are possible solutions to this problem, but they suppose that the international LOLR gets directly involved *ex ante* in the supervisory and safety net policies of countries. For example—as we show below—the financing needs of the international LOLR can be greatly reduced if domestic authorities can commit to use LOLR resources for the exclusive purpose of serving a deposit insurance on foreign currency deposits in domestic banks. Alternatively, the international LOLR could bypass the domestic authorities and lend directly to the domestic private institutions on a case-by-case basis through a discount window. It would probably have, in that case, to also directly supervise and monitor domestic

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<sup>3</sup> The point is in fact more general and could be made in a closed economy context. The general statement is the following: If the multiplicity of equilibria comes from the fact that the price of bank assets is endogenous to the occurrence of the crisis, then restricting the access to lending-in-last-resort to the banks that are solvent *in equilibrium* does not remove the bad equilibrium. The exchange rate opens up a simple channel by which the price of assets goes down in crises. In a closed economy context the same effect could result from a decrease in dividends or an increase in default probability on loans.

banking sectors. These solutions would require, in the terminology of Goodfriend and King (1988), that international lending-in-last-resort be viewed as an input into domestic banking policies, as opposed to domestic monetary policies. Such an evolution is possible in principle, but it would imply an involvement of the international LOLR in domestic banking sectors much deeper than what can realistically be supported by existing institutions and arrangements.

The paper is structured as follows. Section 2 presents the assumptions of the model and characterizes the structure of equilibria. Section 3 analyses the role of an international LOLR. In section 4 we illustrate the implications of the model by looking at the order of magnitude of the main variables in a sample of recent crises. Section 5 concludes.

## 2. The model

We consider a small open economy whose banking sector is fragilized by liquidity and currency mismatches. Domestic banks carry liquid foreign-currency-denominated liabilities that are backed by less liquid assets denominated in domestic currency. The domestic monetary authorities hold foreign exchange reserves which they can use to rescue the banking sector in case of a financial panic. If the amount of reserves is insufficient, they can attract additional reserves from abroad by raising the interest rate or by letting the domestic currency depreciate. Such a policy, however, fragilizes the domestic banking sector by reducing the foreign currency value of domestic assets. Thus monetary policy is caught between two conflicting objectives: attracting capital inflows (or preventing capital outflows) and preserving the banking sector. We investigate in this section the conditions under which this contradiction can be solved at the national level, and consider in the following section the case where international financial assistance is provided.

### 2.1 Assumptions

The model has two periods,  $t=1, 2$ , and four types of agents: the domestic central bank, domestic private banks, depositors, and investors.<sup>4</sup> Depositors and investors may be foreign or domestic residents, but we assume that they assess their payoffs in terms of the foreign currency. For the sake of brevity and *couleur locale* we shall call the domestic and foreign currencies “peso” and “dollar” respectively. We denote by  $S_t$  the price of one dollar in terms of peso at time  $t$ .

#### Banks and depositors

There is a liquidity and currency mismatch in the balance sheet of the banking sector. To simplify the model, we make the extreme assumption that banks’ liabilities are denominated

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<sup>4</sup> Depositors and investors could be the same agents but it simplifies the exposition to consider them separately.

in dollars while their assets are denominated in peso.<sup>5</sup> This currency mismatch is augmented by a liquidity mismatch, in the sense that banks have assets expressed in period 2 pesos but liabilities expressed in period 1 dollars. The menu of assets and liabilities could be enriched without affecting the main results of the paper. There is a number  $N_b$  of identical banks. At period 1 the representative bank has a quantity  $D^*$  of dollar deposits and owns a claim on  $A$  pesos at period 2. This claim can take the form of government bonds, corporate bonds, or loans.

There is a large number of depositors, who decide at  $t=1$  whether or not to withdraw their deposits. Banks repay depositors by selling their assets in exchange of dollars. We assume that banks' assets are perfectly liquid and can be sold for dollars without transaction or liquidation costs. A key variable is the dollar price at period 1 of a claim to one peso at period 2. It is given by:

$$P^* = \frac{1}{(1 + i) S_1} \quad (1)$$

where  $i$  is the peso nominal interest rate between period 1 and 2. We could assume, in line with the theoretical bank run literature, that bank assets are illiquid in the sense that they can be sold at period 1 only at a discount relative to their present value. This would not change the thrust of our results, and it is interesting to see that in fact we do not need this assumption. The illiquidity of banks, in our setting, will be the result of monetary policy.

We assume that if the value of a bank's assets in terms of dollars is insufficient to repay all its depositors, i.e., if  $P^* A < D^*$ , a run occurs. Depositors withdraw their deposits *en masse*, the bank repays some of them by selling its assets for dollars, and then collapses. Conversely we assume that if  $P^* A \geq D^*$  depositors keep their deposits at the bank. Since all banks are identical, depositors run on the whole banking sector or do not run at all. Denoting by  $d_R$  the dummy variable for a bank run (equal to 1 if there is a bank run, 0 if not) the depositors' behavior is described as:

$$\text{(depositors)} \quad d_R = 0 \Leftrightarrow P^* A \geq D^* \quad (2)$$

## Investors

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<sup>5</sup> We assume the existence of the currency mismatch and do not endogenize it. The balance sheet structure of banks is inherited from an earlier time, when it seemed optimal to borrow in dollars and lend in pesos, for example because the interest rate differential seemed high relative to the risk of depreciation, or because the latter risk was insured by implicit government guarantees. Policies that would prevent currency mismatches to arise *ex ante* would also remove the need for an international LOLR.

There is a number  $N_i$  of identical investors endowed with  $W_1^*$  dollars at the beginning of period 1, which may be invested in dollar or peso-denominated bonds. Beginning of period 2 wealth of the representative investor, expressed in terms of dollars, is equal to his initial endowment times the return on dollar bonds plus his investment in peso bonds times the excess return on peso bonds:

$$W_2^* = (1+i^*)W_1^* + r \frac{B}{S_1}$$

where  $B$  is the amount of pesos invested in peso-denominated bonds, and the excess return is given by:

$$\begin{aligned} r &= (1+i) \frac{S_1}{S_2} - (1+i^*) \\ &\approx i - i^* - (s_2 - s_1) \end{aligned}$$

where  $s_t$  denotes the log deviation of the exchange rate from a reference value  $S$ .

We assume that investors choose their portfolio to maximize a mean-variance function of their period 2 wealth  $W_2^*$ :<sup>6</sup>

$$V = E(W_2^*) - \frac{a}{2} \text{Var}(W_2^*)$$

It follows that the demand for peso bonds by an individual investor can be written as:

$$\frac{B}{S_1} = \frac{i - i^* - (E(s_2) - s_1)}{a \text{Var}(s_2)}$$

Note that if the domestic interest rate is lower than the level that would be required by uncovered interest rate parity, investors' holdings of peso bonds is negative ( $B < 0$ ). This possibility will play an important role in the rest of the analysis. It corresponds to short positions in the domestic currency achieved by borrowing pesos from domestic banks.<sup>7</sup>

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<sup>6</sup> This objective function can be derived from the maximization of a CARA utility function when the return is normally distributed.

<sup>7</sup> It is assumed that the banks that lend to speculators have no currency mismatch, and that it is possible to borrow from them without restriction in a crisis.

### The central bank

The domestic central bank enters period 1 with a stock  $R_0^*$  of foreign exchange reserves. The change in the level of official reserves in period 1 results from the balance-of-payments equation:

$$R^* - R_0^* = CA + N_i \frac{B}{S_1} - d_R N_b P^* A \quad (3)$$

where  $CA$  is the current account,  $N_i B/S_1$  is the capital inflow generated by the purchase of peso bonds by investors (or the capital outflow resulting from investors taking short positions in the domestic currency), and the third term is the capital outflow provoked by a run on the dollar deposits at domestic banks. We take the current account as exogenous—a plausible assumption given the short horizon at which crises evolve.

The central bank sets monetary policy in period 1 subject to the constraint that the end-of-period level of reserves be positive:

$$R^* \geq 0 \quad (4)$$

Monetary policy involves the choice of two variables: the interest rate,  $i$ , and the exchange rate,  $s_1$ . These two variables can be chosen independently within the limits set by the reserves constraint (4) since uncovered Interest Parity does not hold in this model because investors are risk-averse.<sup>8</sup> In equilibrium, the nominal interest rate and the exchange rate determine the level of the risk premium, the volume of capital inflows, and the amount of reserves at the central bank. For example, raising the interest rate while keeping the exchange rate constant increases the risk premium, attracts capital flows and raises the quantity of reserves at the central bank.

We assume that the central bank's preferences are lexicographic in the sense that avoiding a banking collapse takes precedence over all other concerns. The central bank first determines whether or not it is possible to set monetary policy so as to avoid a run. It then sets the interest rate and the exchange rate so as to maximize its other objectives conditional on no-run. (The appendix presents a small macro-model in which this prioritization of objectives is derived from more primitive assumptions on the monetary authorities' preferences.)

We assume that the second period exchange rate depends on whether or not the banking sector has collapsed in period 1. Other things equal, a banking collapse tends to depreciate the domestic currency through different channels, some real (involving a disruption of production and a decrease in the output of tradables, for example), other nominal (by

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<sup>8</sup> Uncovered Interest Parity obtains in the limit case where investors are risk-neutral ( $a=0$ ).

inducing the monetary authorities to implement a monetary stimulus, or generating the expectation that they will do so later).<sup>9</sup> We assume that the log deviation of the exchange rate at period 2 is stochastic, equal to  $d$  in average if the banking system has collapsed in period 1, and 0 if not.

Formally:

$$s_2 = \mathbf{d} d + \mathbf{e}$$

$$E(\mathbf{e}) = 0$$

$$Var(\mathbf{e}) = \mathbf{s}^2$$

where  $\mathbf{d}$  is a dummy variable that takes the value 1 in the event of a bank collapse and 0 otherwise, and  $\mathbf{e}$  is the innovation in the exchange rate at period 2.<sup>10</sup> The average rate of depreciation  $d$  is set exogenously; in a more general formulation it could be made dependent on the size of the banking collapse, opening up another channel for self-fulfilling equilibria. Note that in equilibrium the two dummy variables describing the depositors' behavior ( $\mathbf{d}_R$ ) and the event of a bank collapse ( $\mathbf{d}$ ) are equal since depositors run only if they expect a bank collapse. In order to properly define the equilibrium, however, it is preferable to define these variables separately. A bank collapse ( $\ddot{a}$ ) is the outcome of the joint actions of depositors ( $\mathbf{d}_R$ ) and of the central bank ( $i$  and  $s_I$ ).

### Rules of the game

We consider Nash equilibria of the game between the representative depositor and the central bank. The representative depositor decides whether or not to run ( $\mathbf{d}_R$ ) taking the actions of the central bank ( $i$  and  $s_I$ ) as given. The central bank sets monetary policy ( $i$  and  $s_I$ ) taking the decision of depositors as given.

## 2.2. Equilibria

There are two types of equilibria: with a bank collapse, and without. The first type occurs when the central bank is unable to set monetary policy so as to avoid a banking collapse. In

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<sup>9</sup> See the appendix for an endogeneisation of this assumption in the context of a small macro-model.

<sup>10</sup> We consider later the case where the conditional variance of the exchange rate at period 2 depends on whether or not a banking collapse has occurred at period 1—as would occur if the domestic currency is in a fixed currency peg regime which is abandoned if and only if there is a banking collapse.

the second type of equilibria, it can. A crucial factor, then, is the central bank's ability to avoid a banking collapse given the depositors' decision whether or not to run.<sup>11</sup>

The central bank's problem, in equilibrium, is whether it can find a monetary policy that satisfies the reserves constraint (4) and the no-run condition (2). This may be written as:

$$\text{(central bank)} \quad \text{Find } i, s_1 \text{ such that } \begin{cases} R^* \geq 0 \\ P^* A \geq D^* \end{cases}$$

Linearizing (1) and (3) around the exchange rate level  $S$ , and noting that depositors run only if they expect a bank collapse (so that  $E(\mathbf{d}) = \mathbf{d}_R$ ), these conditions become:

$$\begin{cases} R_0^* + CA + N_i \frac{i + s_1 - i^* - \mathbf{d}_R d}{aS^2} - \mathbf{d}_R N_b \frac{A}{S} [1 - (i + s_1)] \geq 0 \\ i + s_1 \leq \bar{x} \end{cases} \quad (5)$$

where  $\bar{x} = \ln(A/SD^*) \gg A/SD^* - 1$ .

These equations show that the variables that matter in the central bank's problem are not the interest rate or the exchange rate taken separately, but their sum,  $x = i + s_1$ . This property will be made easier to interpret by noting that  $x$  is also the inverse of the log deviation of the price of peso bonds in terms of dollars:

$$p^* = -(i + s_1) = -x$$

The two inequalities in (5) capture the dilemma that the central bank faces when setting monetary policy. The first constraint says that in order to maintain a positive level of reserves the central bank must keep  $x$  high enough, i.e. the dollar price of peso bonds must remain below a ceiling. By lowering this price, the central bank increases the demand for peso bonds and thus the level of its reserves. The second constraint says that, to avoid a run,  $x$  should not

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<sup>11</sup> If we consider, alternatively, that the central bank is a Stackelberg leader, there would be no bad equilibrium as it can always choose the good equilibrium.

be too high, i.e. it sets a floor on the dollar price of peso bonds: this is the level under which the value of the banking system's assets is not sufficient to cover its liabilities and a run occurs.

The crucial question, from the central bank's point of view, is whether the reserves constraint and the no-run condition are mutually consistent. This is not necessarily the case: the ceiling defined by the former may be lower than the floor implied by the latter. In that case, the central bank's dilemma has no satisfactory solution: there is no monetary policy that maintains a positive level of reserves *and* preserves the banking system from a run. The reserves constraint imply levels of  $x$  that are so high that they make the banking system collapse.

Whether or not a generalized bank collapse may occur in equilibrium turns out to depend on the initial level of reserves at the central bank. The bank run equilibrium occurs if and only if (5) has no solution given  $d_R = 1$ , i.e.:

$$R_0^* < N_b D^* + N_i \frac{i^* + d - \bar{x}}{a\mathbf{S}^2} - CA \equiv R_0^* \quad (6)$$

Conversely, the no-run equilibrium occurs if and only if (5) has solutions when  $d_R = 0$ , i.e.:

$$R_0^* \geq N_i \frac{i^* - \bar{x}}{a\mathbf{S}^2} - CA \equiv R_{-0}^* \quad (7)$$

The structure of equilibria, hence, may be characterized as follows:

- if  $R_0^* > \bar{R}_0^*$ , there is one unique equilibrium, without banking collapse ( $\delta = 0$ );
- if  $\underline{R}_0^* < R_0^* < \bar{R}_0^*$ , there are two equilibria, one with a banking collapse and one without;
- if  $R_0^* < \underline{R}_0^*$ , there is one unique equilibrium with a banking collapse ( $\delta = 1$ ).

Indeed, when  $R_0^* > \bar{R}_0^*$  the central bank can and will choose  $x < \bar{x}$  and avoid a bank collapse, which makes a run pointless. Conversely, when  $R_0^* < \underline{R}_0^*$  if the central bank seeks to avoid a collapse by setting  $x \leq \bar{x}$  then  $R^* \leq R_0^* - \underline{R}_0^* < 0$ ; this violates the reserves constraint and, knowing this, a run will occur, prompting a collapse. In the intermediate range, the model

gives rise to multiple equilibria. The equilibrium may or may not involve a banking collapse, depending on whether or not depositors coordinate on a run.<sup>12</sup>

The structure of equilibria is reminiscent of “second generation” or “escape clause” models of currency crises, in which multiple equilibria also arise when the exogenous fundamentals enter a “gray zone” (Obstfeld, 1996; Jeanne, 1997). The logic of multiplicity is the same: private sector expectations affect the set of constraints under which policy is determined. A collective run associated with the expectation of a depreciation constrains the central bank to take policy actions—raise the interest rate and/or let the currency depreciate—which effectively weaken the banking sector, and make running the only rational decision for individual depositors.

### 3. An international lender of last resort

Self-fulfilling financial crises arise in equilibrium when the domestic central bank does not have enough foreign exchange reserves. We now consider an institution (the international lender of last resort) that stands ready to lend dollars to the domestic central bank with the objective of removing the “bad” equilibrium. We ask what is the minimum size of the international lender of last resort’s commitment that is required to make its intervention effective.

#### How large is large enough?

The international lender of last resort can remove the run equilibrium by standing ready to lend  $\bar{R}_0^* - R_0^*$ , i.e., the quantity of dollars by which the reserves fall short of the threshold above which there is one unique no-run equilibrium. The required amount of lending-in-last resort intervention, thus, is given by:

$$\Delta R^* = (N_b D^* - R_0^* - CA) + N_i \frac{i^* + d - \bar{x}}{a\mathbf{S}^2} \quad (8)$$

This is the sum of two terms. The first term reflects the *liquidity gap* in the balance sheet of the country, i.e., the amount by which the country’s liquid dollar assets fall short of its liquid dollar liabilities. The second term reflects *currency speculation*. It corresponds to the capital outflows triggered by the expectation of a depreciation of the domestic currency.

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<sup>12</sup> When  $\underline{R}_0^* < R_0^* < \bar{R}_0^*$ , if depositors play  $\delta_R = 0$ , the central bank can play  $x$  that satisfy (5), if depositors choose  $\delta_R = 1$ , the central bank cannot.

The currency speculation term is positive if  $\bar{x}$ , the maximum level at which the domestic authorities can set  $x$  without provoking a banking collapse, is lower than the level required by uncovered interest parity when there is a crisis,  $i^* + d$ . In that case investors take short positions in the domestic currency when monetary policy is set so as to avoid a banking collapse. Note that as investors risk aversion goes to zero, the currency speculation term goes to infinity. The reserves provided by the international LOLR are siphoned out by speculation as soon as they enter the country. Thus our model implies that the international LOLR should have infinite resources in the limit case where investors are risk-neutral. Even if there exists some risk aversion in the market, the liquidity gap may turn out to be a small fraction of the reserves needed in the event of a crisis.

The required amount of lending in last resort depends on the other exogenous variables of the model in the following way:

$$\begin{aligned}\frac{\partial \Delta R^*}{\partial D^*} &= N_b + \frac{N_i}{a s^2} \frac{A}{SD^{*2}} \\ \frac{\partial \Delta R^*}{\partial A} &= -\frac{N_i}{a s^2} \frac{A}{SD^*} \\ \frac{\partial \Delta R^*}{\partial i^*} &= \frac{\partial \Delta R^*}{\partial d} = \frac{N_i}{a s^2}\end{aligned}$$

The ceiling  $\bar{x} = \ln(A/SD^*)$  on the monetary policy instrument  $x$ , which limits the central bank's ability from protecting its foreign exchange reserves, is the banks 'coverage ratio', the ratio of domestic assets to dollar deposits. This ceiling determines the volume of short positions taken by speculators who understand the constraint on the central bank, and thus affects the required amount of lending-in-last-resort:

$$\frac{\partial \Delta R^*}{\partial \bar{x}} = -\frac{N_i}{a s^2}$$

This explains why the required amount of lending-in-last-resort is increasing more than proportionately with the level of banks dollar liabilities  $D^*$ : the second term shows that the sudden realization that a large fraction of bank loans is insufficient to cover dollar deposits increases the required level of lending in last resort—dramatically so if investors are little risk averse—by restricting the ability of the central bank to raise the interest rate and attract reserves. The required amount of lending-in-last-resort is also increasing with the foreign interest rate because it triggers a capital outflow.

### **The irrelevance of the exchange rate regime**

That international financial assistance might be swamped by currency speculation, and does not always achieve its stated aims, is not contradicted by recent experience with financial and currency crises. It is often asserted that such failures reflect a misguided defense of unsustainable currency pegs and that it is much easier to manage floating exchange rates.<sup>13</sup> Some policymakers have even recommended that emergency packages be denied to emerging economies which operate currency pegs (Rubin, 1999).

In our model, however, currency speculation is not a specific problem of fixed exchange rate regimes. Our results so far have been obtained without any specific assumption concerning the exchange rate regime. The monetary policy instrument is  $x = i + s_1$ , allowing the central bank to use any combination of the interest and exchange rates. The occurrence of a banking collapse is only determined by the dollar price of peso bonds  $p^* = -x$ . Whether a given change in this price is achieved by changing the interest rate or the exchange rate is irrelevant for financial stability. While it is true that a floating regime allows the monetary authorities to set a lower interest rate in the face of speculative pressure, the resulting depreciation hurts domestic banks by reducing the dollar value of their peso assets. The apparent margin of maneuver offered by a floating exchange rate, thus, is largely illusory in this model. The reason is that the threat is not a currency crisis (a run on the central bank's foreign exchange reserves) but a bank crisis (a run on dollar deposits in banks).

We note, however, that the model ignores the moral hazard created by a fixed exchange rate commitment. If this commitment is credible enough to rule out a depreciation—or if it is backed by an implicit promise of bailing out domestic borrowers that would be made insolvent by a devaluation-- it provides an implicit guarantee for foreign currency borrowing, thus increasing the size of short positions in the domestic currency (Burnside, Eichenbaum and Rebelo, 1999). Ignoring this important effect, we examine how a fixed exchange rate regime would change our results. Let us assume that the central bank determines monetary policy in period 1 under the constraint of a fixed exchange rate ( $s_1=0$ ) and that in the absence of a banking collapse the fixed peg is also maintained in period 2, that is:

$$s_2 = d(d + e)$$

The central bank's problem (5) would remain unchanged except that  $s^2$  is multiplied by  $d_R$  and  $s_1$  is set to zero. Now, conditional on no-run, (5) has a solution provided that:

$$i^* \leq \bar{x}$$

which replaces (7) as the condition of existence of the no-run equilibrium. The intuition is the following. Since there is no exchange risk regarding next period's exchange rate conditional on no-run, the model behaves as if investors were risk neutral. The sensitivity of capital

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<sup>13</sup> See Eichengreen (1999). Of course this is only one of the arguments against fixed currency pegs.

flows to the interest rate differential becomes infinite and the central bank can attract as much reserves as it wants by setting the domestic interest rate slightly above the foreign level without endangering the banking system.

Conditional on a run, the central bank's problem is exactly the same as before, and the condition for the existence of a run equilibrium remains (6). This result is not surprising since conditional on a run the second period exchange rate is the same whether the country was initially in a floating or a fixed exchange rate regime. The fixed exchange rate regime, hence, does not change the existence of a range of reserves within which the economy is vulnerable to self-fulfilling crises, neither does it change the amount of lending-in-last resort required to prevent them.

### **The subversion of international lending-in-last-resort by domestic monetary policy**

On the other hand, our conclusions are certainly sensitive to the way we have modeled the LOLR policy. We have assumed, in line with Goodfriend and King (1988), that LOLR operations are implemented through open market operations in which the central bank exchange dollars against domestic assets at current market prices.<sup>14</sup> LOLR, in other terms, is just a particularly extreme modality of the monetary operations used in more tranquil times: it does not involve the central bank lending to specific institutions on non-market terms.

It has been argued that such a policy might be optimal to the extent that it ensures that the institutions that are saved from default are solvent—thus mitigating the moral hazard problem associated with lending-in-last-resort.<sup>15</sup> The problem, as our model shows, is that the solvency of financial institutions cannot be taken as exogenous to monetary policy. Raising the interest rate or letting the currency depreciate makes insolvent institutions that would be solvent in the absence of crisis. Trying to keep banks solvent on market terms puts severe constraints on monetary policy and may considerably increase the need for international reserves. A large fraction of the reserves will be used to fight speculation against the domestic currency, instead of going to the illiquid agents who most need them.

There are solutions to this problem, but they suppose that the international LOLR gets directly involved *ex ante* in the supervisory and safety net policies of the countries it lends to. For example, the international LOLR could require the domestic authorities to insure dollar deposits in the domestic banking sector, and to commit to use its loans for the exclusive

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<sup>14</sup> See Freixas and Rochet (1997), chapter 7, for a discussion of different doctrines of lending-in-last-resort.

<sup>15</sup> Capie (1998) attributes this view to Bagehot. Goodfriend and King (1988) argue, in a similar spirit, that lending-in-last-resort should be viewed as part of monetary policy—as opposed to banking policy. Calomiris (1999) invokes a similar argument in his discussion of the international LOLR.

purpose of operating this insurance. Then the LOLR would not have to lend more than the liquidity gap to remove the bank-run equilibrium. Depositors, knowing that the domestic authorities have enough dollars to fulfill their obligations under the deposit insurance no longer have individual incentives to run. Such a scheme, however, would require a credible commitment by the domestic authorities to use lending-in-last-resort for dollar deposit insurance only and not for other purposes, such as foreign exchange interventions.

If the domestic authorities cannot credibly to make a tight separation between lending-in-last-resort and other policy objectives, one solution would be for the international LOLR to bypass the authorities and directly provide deposit insurance on dollar deposits in domestic banks. Alternatively, it could lend directly to the domestic private institutions on a case-by-case basis taking solvency in the no-crisis equilibrium as the criterion of selection. Both policies, however, would require the international LOLR to be directly involved in the supervision of the domestic financial sector—to limit the moral hazard associated with the deposit insurance, or because detailed information on the individual situations of domestic banks would be necessary to assess their out-of-equilibrium solvency.

#### **4. Some empirical illustrations**

The model presented here is far too stark to be literally taken to the data. In this section we turn to a number of prominent cases of recent currency crises to provide rough estimates of the size of the magnitudes involved. We focus on two main issues: how large are the speculative attacks relative to the liquidity gap, and how constrained were the monetary authorities in dealing with speculative pressure? Both questions bear directly on the role of international lender-of-last resort.

##### **Speculative pressure**

The difference between total reserves loss in the midst of a crisis and the liquidity gap—the amount that an international lender-of-last-resort needs to finance to allow a country to keep serving its short-term debt—represents endogenous speculative capital flight. This is the second term in the right-hand side of (8). In theory, this outflow approaches infinity as risk aversion goes to zero, potentially undermining the feasibility of international lending-in-last resort. The volume of speculative capital is not known, of course. Even if it were, what is observable is the outcome of the high frequency interaction between financial markets and central banks. Thus, the evidence that we produce in this section is, at best, a crude ballpark estimate.

Figure 1 above shows the evolution of the liquidity gap in some crisis countries. Table 1 provides a decomposition of (8) for nine cases of twin currency crises, eight as identified by Kaminski and Reinhart (1999) and Korea. The table reports peak-to-trough changes in foreign exchange reserves  $R^*$ , the liquidity component (foreign currency bank deposits)  $D^*$ , and the speculative component  $R^*-D^*$ . The reserves are those reported in *International Financial Statistics*, undoubtedly ignoring a number of items, e.g. off-balance positions. With

exceptions of Argentina in 1988-90 and Korea, the drop in reserves is much more driven by the speculative than by the liquidity component. The last column of Table 1, which shows the ratio between the two components, eloquently makes the case that an international LOLR would often have to provide amounts that exceed by a multiplicative factor the liquidity gap.

[Insert Table 1]

This result is further illustrated by looking at the partial correlation of the change in reserves with each of the two components. Table 2 shows the result of panel data estimates of these partial coefficients using a panel of nine crisis-prone countries over twenty years, including both crisis and tranquil periods, using various methods. The role of the speculative component is about twice as large as the role of the liquidity component. This figure, taken at face value, would suggest that the amount of lending-in-last resort would have to be at least three times as large as the liquidity gap in average.

[Insert Table 2]

Our measure of the liquidity gap is clearly subject to considerable uncertainty. For lack of better data, liquid international liabilities are defined here as all national debts (banks and nonbanks, public and private) with a maturity of one year or less. How well-known is this information and how sensitive are the figures to the definition of short-term or to the choice of debtor? The maturity of claims –which determines the liquidity of both assets and liabilities-- is endogenous to the risk of a crisis (Jeanne, 1999). Figure 1 above shows that the share of short-term claims tends to climb during the period leading to a crisis so that lending-in-last-resort based on a snapshot view of the liquidity gap may turn out to fall significantly short of the needs as markets continue rebalancing their portfolios towards the short end of the maturity spectrum.

### **The bank-run constraint on monetary policy**

A key implication of our model is that the banking system's vulnerability constrains the use of monetary policy to deal with a speculative attack. The no-bank run condition (2) suggests that the ratio of dollar deposits to liquid bank assets in domestic currency ( $D^*/P^*A$ ) is a summary statistics of the impact of bank fragility on the central bank. This condition can be rewritten as:

$$(1 + i) \frac{S_1}{S} \leq \frac{A}{SD^*} = 1 + \bar{x} \quad (2')$$

This condition can be interpreted as setting a ceiling on the domestic interest rate given the exchange rate. More generally, it maps out the combination of interest rates and exchange rate depreciations ( $S_1/S$ ) which are compatible with the absence of a run. We interpret here  $S$  as the pre-crisis exchange rate and  $S_1$  as the other policy instrument of the central bank.

Using BIS data we plot the estimated  $1 + \bar{x}$  in Figure 2 for the nine cases considered in Table 1 (for a description of the data, see Appendix 2). One way of interpreting this variable is to note from (6) and (7) that:

- if  $\bar{x} > i^*$  then  $\underline{R}_0^* < 0$  in which case, as long as  $R^* > 0$  there is an equilibrium in which the central bank avoids a bank collapse; this corresponds roughly to value of  $1 + \bar{x}$  in excess of 1.05 if bank assets have a maturity of one year and the foreign interest rate is equal to 5 percent.

- if  $\bar{x} > i^* + d$  then  $\bar{R}_0^* < 0$  in which case, as long as  $R^* > 0$  there is no risk of bank collapse; this corresponds roughly to value of  $1 + \bar{x}$  in excess of 1.25 if we consider 20 percent as a normal depreciation at a one-year horizon.

The other margin available to the central bank when dealing with central bank fragility is shown in (8) as  $R^* - D^*$ , the difference between the foreign exchange reserves and dollar deposits.

Given both the simplicity of the model and the discrepancy between available data and their theoretical counterpart, one should not take the above thresholds too seriously. In nearly all instances the crises follow a period when  $\bar{x}$  has been declining, usually falling below the thresholds. There are also instances (Indonesia in the early 1990s, Chile in the late 1980s, not shown) when  $\bar{x}$  reached very low levels and yet there was no bank collapse. This is compatible with our model if there are enough reserves to conduct domestic lender-of-last-resort operations without having to tighten up monetary policy to hold enough reserves.<sup>16</sup>

The figure also displays  $R^* - D^*$ , the other central bank margin to fight speculation, i.e. foreign exchange in excess available after bailing out banks in case of a run on foreign currency deposits. With drops in reserves in the \$ 10-20 billion range fairly common, the figure might be taken to suggest that, by end 1996, Korea looked reasonable safe, while Thailand was doomed, with Indonesia and Malaysia in the danger zone.

[Insert Figure 2]

This conclusion might not be warranted though when we take into account the no-bank run constraint. Korea, which was widely believed to be safe until very late 1997, serves as a good example. To see that this was not the case, we draw the interest-exchange rate frontier

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<sup>16</sup> Given our assumption of lexicographic preferences, we do not study the central bank's response to the actual occurrence of a bank run when reserves would not be exhausted.

described by (2'), the combination of the interest rate factor  $I + i$  and of possible depreciation  $S_I/S$  that satisfy (2'). The frontier is shown for two observations: end of 1995 and end of 1996. According to this calculation, the Korean central bank faced no serious problem in 1995 but was already in a bind by end 1996. The figure suggests that the won would have had to *appreciate* by 10 percent—thus raising the dollar value of won-denominated bank assets—for the maximum interest rate to be just positive.

[Insert Figure 3]

## 5. Conclusions

The main result of this paper should be to instigate a solid degree of skepticism regarding the feasibility of international LOLR without sweeping institutional reforms. If the international LOLR relies on domestic monetary authorities to allocate its funds, the model presented here vindicates those who claim that it must stand ready to provide virtually unbounded amounts of currency. Central banks satisfy this condition, not any existing international financial institution. For example, the IMF's resources are already stretched after several interventions where it undertook to match the liquidity gap, it is unlikely that it could go much beyond. The alternative is an international LOLR that is directly involved in the supervision of the domestic banking systems that it might be called upon to rescue.

An interesting by-product of the paper is to interpret the trade-off that central banks often face at the time of currency crises. A vigorous interest rate defense weakens the banking system. If banks are fragile, central banks risk triggering a bank run and, if reserves are not large enough, they may end up with both a currency crash and a bank collapse. On the other hand, letting the currency go is not a solution either, since this also fragilizes the banking system by decreasing the dollar value of its assets. This dilemma explains part of the debate that has arisen after the Asian crisis, between those who favored a vigorous interest rate defense and those who called for a sharp decline in interest rates.

The model presented here suffers from a number of limitations. Having assumed a lexicographic ordering, we do not study the central banks' optimal policy following a bank collapse. The role of expectations is brought down to a strict minimum yet, it matters whether there exists a LOLR. The possibility of such interventions may deter a bank run, or encourage it when moral hazard sets in. Exploring this avenue may tell us more about the link between lending-in-last-resort and banking regulation.

In addition, the model glosses over several important moral hazard issues. This includes the role of a fixed exchange rate as an implicit guarantee on foreign borrowing and the effect of a LOLR on risk taking. The role of banks is stripped down to the bare minimum, although a richer menu of assets and liabilities is unlikely to change our key results. Finally, it should be noted that if regulation prohibited open currency position by banks is effective, none of our results obtain. Then, however, we would need to take into account that firms rarely face such a regulation. If the corporate sector becomes insolvent as banks do in our model, and

precipitate bank failures, our results stand.

### Appendix 1: A Macro-model of Central Bank Behavior

This appendix presents a small model providing “macrofoundations” for some of the assumptions made in the text. Let us assume that the domestic authorities minimize the following loss function:

$$L_t = y_t^2 + Is_t^2$$

at time  $t=1,2$ .

The deviation of output from its natural level is given by:

$$y_1 = as_1 - bd$$
$$y_2 = as_2 - bd + h$$

These equations say that in both periods output is increasing with the nominal exchange rate and decreased by a banking collapse. (An implicit assumption is that because of nominal stickiness in the price or wage level, changes in the nominal exchange rates are reflected in their real counterparts.) The second equation also says that the second-period level of output is affected by a shock,  $h$ .

The authorities minimize their loss function in a discretionary way in period 2, i.e. they solve the problem:

$$\min_{s_2} L_2 = (as_2 - bd + h)^2 + Is_2^2$$

taking  $d$  as given. The solution can be written as in the text,  $s_2 = dd + e$ , with  $d$  and  $e$  given by:

$$d = \frac{ab}{a^2 + 1}$$
$$e = -\frac{a}{a^2 + 1}h$$

We now show that the behavior of the domestic monetary authorities are lexicographic in the sense given to that term in the text, i.e., they always try to avoid a banking collapse if possible. The central bank’s first-period problem is:

$$\min_{s_1, i} L_1 = (as_1 - bd)^2 + Is_1^2$$

subject to the reserves constraint:

$$R_0^* + CA + N_i \frac{i + s_1 - i^* - \mathbf{d}_R d}{a\mathbf{S}^2} - \mathbf{d}_R N_b \frac{A}{S} [1 - (i + s_1)] \geq 0$$

and the no-run condition  $\mathbf{d} = \mathbf{d}_R \Leftrightarrow i + s_1 \leq \bar{x}$ . It is not difficult to see that whenever possible, the central bank will set  $s_1$  to 0 and the interest rate to any level that satisfies the reserves constraint and the no-run condition. This will set the authorities' loss function to its absolute minimum  $L_I = 0$ . This necessarily dominates an equilibrium with a banking collapse, since in that case the loss function must be strictly positive. Hence the authorities prioritize their objectives in the way assumed in the text, trying to avoid a banking collapse first and then optimally setting the interest rate and the exchange rate conditional on no-run.

## Appendix 2. Data Definitions and Sources

**Foreign currency bank  $D^*$ .** There is no direct information on foreign currency deposits in local banks. One proxy is the series on foreign liabilities of commercial banks from *International Financial Statistics* (line 26c). This is a very imperfect proxy which requires assuming that all foreign liabilities are in foreign currency and ignores foreign currency by domestic residents, where allowed. Some foreign liabilities may be in local currency, in which case the series overestimate  $D^*$ . As we are concerned with bank runs, however, it is highly likely that foreigners run on local deposits whatever the currency of denomination and promptly sell local currencies on the foreign exchange market, effectively against central bank reserves. Ignoring claims in foreign currency by domestic residents is more problematic and may lead to a serious underestimate.

**Liquid assets of banks  $P^*A$ .** We use the series in *International Financial Statistics* which are likely to represent liquid assets, chiefly claims on public entities (central bank and government) and other financial institutions (in general the sum of lines 20, 22a, 22b, 22f and 22g). This may be an overestimate of the theoretical concept since there may not be markets for all these assets and institutional restrictions may apply. It may also be an underestimate of the funds that banks may mobilize to face a run. In particular, some foreign assets may also be liquid. Integrating them (line 26d) does not substantially alter the time profile.

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**Table 1. Peak-to-trough decline in reserves (US\$ billion)**

Crisis	Change in:			Ratio
	$R^*$	$D^*$	$D^* - R^*$	$\frac{\Delta(D^* - R^*)}{\Delta D^*}$
Argentina (Aug.1980-July 1981)	5.8	-9.9	15.7	$\infty$
Argentina (June 1986-Sept.1987)	2.9	-0.3	3.2	$\infty$
Argentina (Dec.1988-Feb.1990)	5.1	3.0	2.1	0.7
Chile (Sep.1981-Sept.1982)	1.6	0.0	1.6	$\infty$
Thailand (Nov.1984-Feb.1985)	0.7	0.0	0.7	$\infty$
Indonesia (June 1997-Feb. 1998)	12.0	-1.8	13.8	$\infty$
Korea (July-Dec. 1997)	17.9	16.7	1.2	0.1
Malaysia (Mar.1997-Jan.1998)	16.6	4.1	12.4	3.0
Thailand (Jan.-Aug.1997)	13.3	4.3	9.1	2.1

Source: *International Financial Statistics* (CD-ROM)

Note: The table decomposes the reserve loss at crisis time into a "gap" component,  $\Delta D^*$ , and a "speculation" component,  $\Delta(D^* - R^*)$ , between the months when  $R^*$  reached its peak and its trough. These months are indicated in each case. The last column shows the ratio between the two component, conventionally set to  $\infty$  when the decline in  $D^*$  is non-positive. Data are for end of month.

**Table 2. Partial correlations in panel data**

Dependent variable:  $DR^*$

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Independent variable	OLS	Fixed effect	Random effect
$DD^*$	0.37 (8.96)	0.40 (3.50)	0.41 (9.78)
$D(R^*-D^*)$	0.91 (107.78)	0.84 (12.95)	0.84 (73.66)

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Source: *International Financial Statistics*, CD-ROM

Note: Sample (227 observations) include Argentina, Brazil, Chili, Columbia, Indonesia, Korea, Malaysia, Mexico, Tahiland, monthly data 1980:2-1998-11, unbalanced panel due to missing data for some countries over sub-periods.