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A Simple Model of an International
Lender of Last Resort

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Abstract

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This paper develops a simple model of an international lender of last resort (IOLLR). The world economy consists of many open economies, each with a banking system and a central bank operating under a pegged exchange rate regime. The fragility of the banking system and the limited ability of a domestic central bank to provide international liquidity together can cause currency and banking crises. An international interbank market can help an economy with the needed international liquidity, but with potential costs of international financial contagion. An IOLLR can play a useful role in providing international liquidity and reducing international contagion.

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I. INTRODUCTION

The frequency and magnitude of bank crises has increased in recent decades. Most of these, e.g., the Japanese banking crisis, the Scandinavian banking crises, the US S&L episode have been primarily domestic, and have been resolved by various domestic measures. Several of these involved the Central Bank (CB) in Lender of Last Resort (LOLR) mode. In this context, we developed a model of LOLR (Goodhart and Huang, 1999), which sought to examine the benefits and costs of LOLR in a closed economy in both a static and a dynamic system. In the latter dynamic version, both moral hazard and contagion risks were time varying.

Since the recent Asian crisis, coming on top of the prior Mexican crisis with its associated "tequila effect", there has been increasing interest in the possible need for an International Lender of Last Resort (ILOLR), against a background of perceived potential international contagion.¹ In this paper, we attempt to develop a model of international financial contagion and to examine the role of an international lender of last resort. Our second main objective is also a direct response to Fischer's (1999) call for research on this topic.

The first objective of this model is to try to endogenize one aspect of international financial contagious risk. There are a few recent models which try to attack this issue. These include Aghion, Bolton and Dewatripont (1999), Allen and Gale (1998, 1999), Chang and Velasco (1998), Goldfajan and Valdes (1998), Huang and Xu (1998), and Morris and Shin (1999), to name a few. Aghion, Bolton and Dewatripont (1999) develop a theory of bank failure contagion in a closed economy. They also focus on the issue of the interbank market; in their paper contagion is caused by pure liquidity shortage. Allen and Gale (1998), in a Diamond and Dybvig (1983) one-bank framework, show that bank runs are related to the business cycle, rather than being the results of simple "sunspots." Financial contagion in Allen and Gale (1999) is caused by the interconnectedness of investors in an incomplete market. Open economy is not the focus of either paper. Both Chang and Velasco (1998) and Goldfajan and Valdes (1998) extend the Diamond and Dybvig (one-bank) model into an open economy model, and they show that the illiquidity of the domestic financial system is at the center of the financial crisis. They do not address the issue of the operation of the interbank market. Huang and Xu (1998) focus on financial institutions in generating financial contagion, and here the interbank market plays a key role in creating conditions for financial crisis. Again they do not address open economy issues. Morris and Shin (1999), through analyzing and pricing the coordination failure among creditors, reach an interesting conclusion on transparency in that greater provision of information to the market does not necessarily mitigate the coordination problem. In sum, these papers either deal with financial contagion in a closed economy, or examine issues of international financial contagion but treated contagion as given.

¹ See Giannini (1999) for analyses of LOLR from international perspectives, and Prati and Schinasi (1999) for analyses from European perspectives.

Our paper is closely related to, and builds on, Aghion, Bolton and Dewatripont (ABD henceafter) in modeling contagion, to Diamond and Rajan (1998) in modeling the sources of liquidity shock, and to Krugman (1979) and Goldfajan and Valdes (1998) in dealing with open economy issues. We follow ABD in focusing our attention on interbank market, whose collapse would cause a run on the whole banking system.² Obviously we are interested in the international interbank market, whose collapse would cause a run on the whole domestic banking system of a country, or of several, possibly many, countries. ABD also focus entirely upon illiquidity problems. Our own view is that illiquidity rarely appears unless there is a suspicion of insolvency (or in the international context of [partial] default), given the breadth, depth and efficiency of (international) wholesale money markets. However we proceed one step at a time. For the time-being we shall follow ABD in concentrating primarily on liquidity issues and hope to extend our analysis also to default issues in subsequent papers. While ABD focuses on the interbank problem, their model is also a model of closed economy. By incorporating an element from the balance of payment (BOP), suggested by Krugman (1979) and Goldfajan and Valdes (1998), into the ABD model, we build an open economy model with several economies. We seek to analyze conditions under which international financial contagion emerges, and how an international lender of last resort can play a useful role.

The basic intuition of the model is as follows. There are many economies linked by the international financial market, each with its own banking system and its own central bank which uses its reserves to manage a pegged exchange rate.³ As in Diamond and Rajan (1998), the model has two periods (three dates), and depositors can be of either type-1 or 2, who can only consume during that period of time. There is also an international (bank) depositor, who invests one period at a time, but can roll-over his deposit. The returns from (illiquid) investments of the foreign bank are paid in foreign currency. If any portion of the returns from the investment of the domestic bank is foreign currency, it will place it with its CB and receive domestic currency in its place.

As in Diamond and Dybvig (1983), if there are too many early withdrawals for a deposit bank during period 1, then a bank run can happen. The interbank market serve as a co-insurance mechanism, which in equilibrium would provide the needed liquidity to prevent a bank run from breaking out. But this is not always possible. First, the illiquidity shocks may be too widespread. Banks with benign liquidity conditions, even though they want to lend (since there is no solvency risk by construction), do not have enough funds. As in ABD, the failure of the (international) wholesale market to work signals a systemic insufficiency of liquidity, and that triggers a systemic run. Second, the inability of the banks to meet the adverse liquidity shock may also signal that foreign currency returns are (temporarily) low. This may trigger a run by the international depositors on the foreign currency reserves of

² This is a simpler mechanism than Huang and Xu (1998), in which the collapse of interbank market is due to the information asymmetry problem in their model.

³ Why each economy started with a pegged exchange rate is outside our model.

the CB. While the domestic CB can handle the domestic currency implications of internal liquidity by LOLR, it cannot do so for the foreign currency effects. In this latter context, an ILOLR can play a useful role.

The paper is organized as follows. The model is set up in Section 2. The analysis of banking and currency crises without an international interbank market or ILOLR is presented in Section 3, which is followed by the analysis of banking and currency crises with an international interbank market but no ILOLR, in Section 4. How an ILOLR can play a useful role is examined in Section 4, and our conclusion is in Section 5.

II. The Model

Our basic model is built on the ABD model, with a key innovation to capture the effects of an open economy. In order to extend the interbank market from a closed economy model into a model of an international interbank market, we have: 1) added international investors to each economy; 2) added a CB to each economy; and 3) specified that one key role of the CB is to use foreign reserves to maintain the pegged exchange rate.

A. Depositors

There are N open economies, and ex ante each economy has 2 mass-1 depositors, one domestic and the other international. The domestic investors make deposits in their own domestic currency and consume goods provided by the domestic economy. Although the international investor also deposits in domestic currency, it has to convert the returns/withdrawals into an international currency, say US dollars, to purchase consumption goods.

The model has three date (two periods). At date 0, each depositor invests $I = 1$ in that economy. As in Diamond and Rajan (1998), at each date $t \in \{1, 2\}$, a mass-1 of depositors whom we term “*type- t depositor*” has access to an unverifiable trading opportunity of gross return of B_t at date t , if an amount of $I = 1$ is invested in this new project. At date 0, neither of the depositors know their type. At date 1, both type-1 and type-2 depositors will know their type. The international investors do not know their type at date 0, and they can be of either type-1, or 2 depositors.

Banks exist, as in Diamond and Dybvig (1983), because of their role in creating liquidity according to a standard demand deposit contract.⁴ According to the demand deposit

⁴ We will stick to the standard deposit contract for the sake of simplicity, although we are aware of some criticisms about the use of such a standard deposit contract.

contract, any depositor is allowed to withdraw r_t at time t if they decide to withdraw. If B_t is sufficiently high, an optimal deposit contract will give $r_1 = 1$.

B. Bank/Economy

Each economy has a banking system, which also has its own interbank market. ABD has examined some of the problems for the operation of the domestic interbank market in their earlier paper. To focus on the effects of an open economy and for the sake of simplicity, we choose to treat each economy as having a single bank and focus our analysis on the international interbank market. We can thus use bank and economy interchangeably.

Each bank or economy invests the deposits it has taken in a partly illiquid project which generating return R_t at date t for $1 \leq t \leq 2$. Moreover, at date 1 the revenue R_1 is fully liquid, but the remaining return R_2 is not so. The bank cannot generate additional liquidity beyond R_1 until date 2, unless it liquidates a portion or all of its assets, and doing so can generate additional liquid revenue of γR_2 , where $\gamma < 1$. We assume that the project(s) that the bank is financing is exporting its output, and that the bank is paid in foreign currency.

C. Central Bank

Each economy also has a central bank. Following Krugman (1979) and Goldfajan and Valdes (1998), we assume that the central bank is an agent with a mandate to maintain a fixed exchange rate at an initial rate of 1. The central bank intervenes in the foreign exchange market to maintain the peg. Due to possible shocks to the current account, the central bank's net reserve is X_t , which is only known at date t . We further assume that if the capital outflow F_t at date t , as the result of earlier withdrawals by the international investors, is less than X_t , then the central bank keeps the peg. Otherwise, the central bank would have to devalue and as a result, a balance of payment crisis may occur unless the central bank can get any help from the international interbank market or from an international lender of last resort.

III. Banking and currency crises without an international interbank market or ILOLR

We start our analysis from the benchmark case when there is no international interbank market, or an international lender of last resort. In this benchmark case, both banking and currency crises are possible equilibrium outcomes.

As described above, at date 1, R_1 is fully liquid, but R_2 remains illiquid until date 2. Any liquidation of the remaining investment at date 1 can only generate $\gamma < 1$ for each US dollar of investment, so that if there is a depreciation of the domestic currency of, say k

percent ($k < 1$), the domestic return is γk , whereas the foreign currency return is $\gamma < 1$. In this Diamond-Rajan setup, unlike that of Diamond and Dybvig, the liquidity shock is derived from depositors' outside investment opportunities, rather than their preference shocks. As in Diamond and Dybvig, however, a self-fulfilling rational panic can break out at date 1. In our model, due to the existence of international investors, a bank run can also trigger a currency crisis.

In the benchmark case where a bank faces no uncertainty on their investment, there would be no liquidity shock. Thus, for $R_1 \geq 1$ and B_1 is sufficiently large, and if there is perfect competition between banks for deposits, then the optimal demand deposit contract is:

$$\begin{aligned} r_1 &= 1, \\ r_2 &= R_1 + R_2 - 1. \end{aligned}$$

When the bank faces liquidity shocks, however, a bank run becomes a possibility. As in ABD, if we assume that

$$(R_1, R_2) = \begin{cases} (\bar{R}_1, \bar{R}_2) & \text{with probability } p \\ (\underline{R}_1, \underline{R}_2) & \text{with probability } 1 - p \end{cases},$$

where $\underline{R}_1 < 1 < \bar{R}_1$, $1 < \underline{R}_2 < \bar{R}_2$, $\underline{R}_1 + \underline{R}_2 > 2$. In this case, if B_1 is sufficiently large and p is sufficiently close to 1, and if there is perfect competition between banks for deposits, the same optimal demand deposit contract holds. That is

$$\begin{aligned} r_1 &= 1, \\ r_2 &= R_1 + R_2 - 1. \end{aligned}$$

But now with probability $1 - p$ type-1 depositors would not be able to fully withdraw their deposit at date 1, because the bank would be short of money at that moment. Moreover, if

$$\begin{cases} \underline{R}_1 + \alpha \gamma k \underline{R}_2 = 1 \\ (1 - \alpha) \underline{R}_2 \leq 1 \end{cases}, \quad (1)$$

the bank would have to liquidate (α portion of) its investment at date 1 to meet the demand withdrawal for type-1 depositors. Due to the heavy discount factor, $\gamma < 1$, the required portion for liquidation, α , can be so large that there would be little left for type-2 depositors. Then, it would be in type-2 depositors' interest to withdraw at date 1 as well.

Therefore, even though the bank might have always been solvent a priori, due to the fact that

$$\bar{R}_1 + \bar{R}_2 > \underline{R}_1 + \underline{R}_2 > 2,$$

because of the liquidity shock, there is a banking crisis with the probability of $1 - p$.

If all the investors were domestic, once a CB is in place, there is no real problem (since there is no insolvency). The CB just lends $1 - \underline{R}_1 < 1$, to the commercial bank against the collateral of high expected return $\underline{R}_2 > 1$. But the situation becomes more complex once

we include international investors. We assume that the commercial bank's foreign currency earnings are paid over to the CB, so that so long as the exchange rate peg is held, X_1 (the CB's foreign currency holdings) equal \underline{R}_1 . When \underline{R}_1 occurs, X_1 by definition is less than 1. If the international investors should liquidate, because they fear that the CB may run out of foreign currency assets, then the CB is powerless. Moreover, if condition (1) is satisfied, then the commercial bank will also become insolvent. As a result, the CB cannot lend without loss against \underline{R}_2 , since it has been sold to meet the foreign currency demands of the international investors.

In this case, if we assume no domestic insolvency problems, a CB can always prevent a domestic liquidity crisis. But a foreign currency liquidity crisis can trigger both a currency crisis and a domestic banking crisis.

Proposition 1 *When there is no international interbank market or international lender of last resort, a currency crisis will occur with probability $1 - p$, which will further trigger a domestic banking crisis under condition (1).*

IV. Banking and currency crises with lending by an international interbank market

When all the N economies are linked by an international interbank market, the interbank market may be able to provide the needed liquidity, and thus reduce the probability of a currency crisis, and thus a banking crisis, in each economy. Consistent with the ABD model, with this liquidity provision comes an **international** contagious risk.

To focus on the liquidity issue, we can imagine that, in the international interbank system, M banks (or economies) are subject to a pure liquidity shock, whereas $N - M$ are not. That is, M banks face liquidity shock:

$$(\underline{R}_1, R - \underline{R}_1),$$

where $\underline{R}_1 < 1 < R - \underline{R}_1$, and $R = R_1 + R_2 > 2$ is not changed. This is a scenario in which those bank subject to liquidity shocks are unable to meet the demand withdrawals by international depositors at date 1, but their total returns have not been changed.

The rest $N - M$ banks face no liquidity shock, and thus their returns are

$$(\underline{R}_1, R - \underline{R}_1),$$

with $\underline{R}_1 > 1$, and $R = R_1 + R_2 > 2$.

The M banks would have incentives to borrow from the other banks in order to meet the demand withdrawals at date 1 so that a currency crisis and possibly a banking crisis can be avoided. But the rest $N - M$ may not have incentives to lend their excessive liquidity to

them, unless the illiquid banks are solvent and can provide collateral to insure the liquidity they intend to borrow. Indeed this is possible, given the fact that we have assumed

$$R = R_1 + R_2 > 2,$$

and thus $R - \underline{R}_1 > 1$ always holds. Thus, the illiquid banks may be able to use their date-2 foreign currency income as the collateral to borrow from these $N - M$ banks which are not subject to a liquidity shock. For the whole interbank market, as long as

$$M\underline{R}_1 + (N - M)R_1 > N,$$

there is enough liquidity in the interbank system to save all the illiquid banks.

If, on the other hand,

$$M\underline{R}_1 + (N - M)R_1 < N, \quad (2)$$

there would not be enough liquidity in the interbank system to save all the illiquid banks. As a result, some banks would have to face a currency run, which can further trigger a domestic banking crisis.

If one bank fails to meet the demand withdrawals at date 1, and if we further assume that for this bank,

$$\begin{cases} \underline{R}_1 + \alpha\gamma k(R - R_1) = 1 \\ (1 - \alpha)(R - R_1) \leq 1 \end{cases}, \quad (3)$$

then the failure of one bank sends out a critical signal and informs all the depositors, in every bank and economy, that the international interbank system has exhausted its available liquidity at date 1. As a consequence of such a (true) reasoning, all type-2 depositors should start to run on their own bank and economy, and a collapse of the international interbank system emerges as a Nash equilibrium! Moreover, this international currency crisis will certainly trigger an international banking crisis.

When there is no international lending provided by the international interbank market, the probability of an international banking crisis is only

$$\phi \equiv (1 - p)^N. \quad (4)$$

When N is quite large, this probability becomes quite slim. Remember, however, that we are assuming that all banks are solvent a priori!

With the existence of international interbank lending, however, the probability for a systemic collapse in the international banking system, owing to pure liquidity shortages, is

$$\omega \equiv \sum_{J=1}^{M^*} \binom{N}{J} p^J (1 - p)^{N-J}, \quad (5)$$

where M^* is defined as the largest integer satisfying:

$$M^* \underline{R}_1 + (N - M^*)R_1 < N. \quad (6)$$

It is easy to see that $\omega > \phi$ when the total number of economies, N , is not too small, or the probability of good state, p , is not too large. Therefore, although the international

interbank market provides risk sharing among all participant banks, its existence also could create conditions for international financial contagion.

To summarize, we have the following proposition.

Proposition 2 *When there is an international interbank market, the collapse of the whole international interbank system could happen with a much higher probability than when each bank or economy acts independently.*

V. International Lender of Last Resort

Having analyzed this assumed form of international contagious risk, we are ready to analyze the role of a possible international lender of last resort (IOLR), in dealing with such international banking and currency crises.

From the above condition (2), it is clear that the total liquidity needed in the whole system is L , where

$$L \equiv N - [MR_1 + (N - M)R_1]. \quad (7)$$

With L in place, then the currency crisis, with its further consequence in triggering a banking crisis, can be prevented.

Moreover, the total amount of liquidity, L , when the interbank market is functioning, is much smaller than the amount needed when each bank/economy is in isolation. In the latter case, the amount needed would be

$$\hat{L} = M(1 - R_1). \quad (8)$$

It is straightforward to show that

$$\hat{L} > L,$$

because the interbank market itself can provide $(N - M)(R_1 - 1) > 0$ amount of liquidity.

Thus, we reach the following proposition.

Proposition 3 *When there is an international interbank market, the total amount of necessary liquidity to meet pure liquidity shocks, to be provided by an international lender of last resort, is smaller than that when there is no international interbank market.*

VI. Concluding remarks

We have developed a simple and restricted model of an international lender of last resort. In our model, the World economy consists of many open economies, each with its own banking system and its own central bank which uses its reserves to manage a pegged exchange

rate. We have shown that it is the fragility of the banking system and the limited ability of a domestic central bank to provide international liquidity that causes currency crisis, which further triggers a banking crisis. Although an international interbank market can help the economies with the needed international liquidity, we have demonstrated that this risk-sharing feature also comes with costs of international financial contagion, and that the international contagious risk is much higher when there is an international interbank market than otherwise. Our analysis has indicated that an ILOLR can play a useful role in providing international liquidity and reducing such international contagion.

International financial contagion is an important issue, especially after the recent Asian financial crisis. To the best of our knowledge, this is the first model of ILOLR, in part to respond Fischer's call for research in this area.

In order to make our point as simply as possible, we have made several crucial assumptions, especially we have assumed away all solvency problem, and concentrated on pure liquidity concerns. We have also chosen to focus on the international interbank market, especially the liquidity issue in this market. Moreover, we have assumed that each open economy chooses to peg its exchange rate for reasons outside our model. We did not address the effects of moral hazard and the possible tradeoff between moral hazard and international financial contagion. We plan to address some of these issues in our future research. We accept that most banking/currency crises do incorporate concerns about solvency, so that the present model is hardly fully realistic, but research is conducted one step at a time. We believe that this paper is a useful first step on a long march.

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