Liquidity and Twin Crises[1]

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Abstract

This paper proposes a simple analytical framework for understanding "twin crises" - i.e. crises where a currency crisis and banking crisis occur simultaneously, and reinforce each other. The distinguishing feature of such crises is the spill-over effects across financial institutions through collateral constraints, declines in market values of assets, currency mismatches on the balance sheet and the endogenous amplification of financial distress through asset sales. We explore the role of liquidity, and the role of monetary policy in such crises. In particular, a central question is whether raising interest rates in the face of a twin crisis is the appropriate policy response. Raising interest rates has two countervailing effects. Holding the domestic currency becomes more attractive (other things being equal), but the value of the domestic banking system falls due to the fall in asset prices. When assets are marked to market, there is a potential for endogenously generated financial distress that leads to a collapse of asset prices, as well as the exchange rate. It is thus possible that raising interest rates can have the perverse effect of exacerbating both the currency crisis and the banking crisis.

1 Introduction

Many instances of financial crises through history have exhibited the characteristics of a "twin crisis" in which an attack on the currency coincides with a crisis in the banking system.[1] The Asian financial crisis of 1997 is perhaps the most vivid illustration of such crises, but there have been many similar episodes throughout history, across a wide geographical range, such as the financial crisis in Germany in 1931[2], the Mexican crisis of 1994/5, and the Turkish crisis of 2000. In the case of the Asian crisis, the vulnerability of the financial system arose from the conjunction of two features - the currency mismatch on the balance sheets of the domestic borrowers, and a managed or fixed exchange rate. Domestic financial institutions engaging in "dollar carry" transactions would borrow in foreign currency (dollars) with a lower interest rate, and lend out in the domestic currency at a higher interest rate. With a fixed exchange rate, such a transaction would be profitable for the domestic financial institution, but make it vulnerable to a devaluation of the domestic currency.

One of the most difficult policy questions for the monetary authorities facing a twin crisis is how to conduct monetary policy in the face of the crisis. On the one hand, tightening monetary policy, by raising domestic interest rates, makes it more attractive to hold the domestic currency and also raises the costs of speculating against the currency. Therefore, raising interest rates has the potential to offer relief to a currency under pressure. During the Korean financial crisis of 1997, the policy prescription of the IMF was to conduct tight monetary policy for these reasons.

[1] There is a large literature. See Kaminsky and Reinhart (1999) for an overview of the evidence.

[2] See Schnabel (2001) for an account of the 1931 crisis in Germany.

However, there are also negative consequences of a tight monetary policy. Higher interest rates lower the value of the assets held by the banking system, both through the higher discounting of future flows, but more importantly, through the financial distress to banks and their borrowers, and through distressed liquidations and the economic losses that result. Frequently, such loans will be collaterialized by marketable financial assets but more often will be collaterized by less liquid assets such as land or other real estate. As asset prices fall across the board, the credit quality of loans will deteriorate and the market value of the collateral assets will fall, inducing banks to demand more collateral or to curtail existing lending. Kim (1999) outlines the empirical evidence from Korea during the 97 crisis. When viewed from the outside, the net worth or equity value of the whole of the domestic banking sector will decline.

Foreign lenders will view such developments with concern. The decline in net worth of the banking system represents an alarming deterioration of the credit quality of the borrowers to whom they have lent. Prudent risk control belatedly reasserts itself as the dominant theme in the foreign banks' dealings with the distressed borrowers. They become reluctant to roll over their dollar loans to the domestic banking system, weakening still further the balance sheet positions of the domestic banks and inducing further sales of domestic assets. The repatriation of funds weakens the domestic currency further, fuelling the vicious circle. The net effect of higher interest rates may thus lead to the perverse result of exacerbating the currency crisis. Some (e.g. Radelet and Sachs (1998)) have argued that the IMF's policy prescription during the Asian crisis was misguided in this respect.

Thus, the dilemma for the monetary authorities can be stated as follows. In order to relieve the pressure on the currency, interest rates must

be raised. However, raising interest rates also lowers the asset value of the domestic banking system, and has the potential to trigger the acceleration of repayment demands against the dollar liabilities of the banking system. Such demands can be met only by further disposals of domestic assets, giving another twist to the downward spiral of asset prices, further weakening the banking system. The interaction of the acceleration of dollar liabilities and distressed asset sales has the potential to generate a downward spiral in which falls in the exchange rate and asset prices reinforce each other.

The overall effect of an interest rate increase on the pressure on the currency can thus go either way. An increase in interest rates could strengthen the currency by making it more attractive to hold, or it could precipitate the rush for the exits by the foreign lenders, exacerbating the currency crisis. Such policy debates have been an important feature of recent crises[3].

The link between asset prices and monetary policy is most glaring in those economies that have chosen to give up autonomous monetary policy in favour of a monetary board system, such as in Hong Kong where the currency is pegged explicitly to the dollar. In such economies, there is little discretion in monetary policy in response to external shocks. The "double play" used by speculators against Hong Kong was the ploy in which speculators sold both the Hong Kong dollar and the Hong Kong stock market. If the currency board were held in place, the higher interest rate would adversely impact the Hong Kong stock market, benefiting the speculators. If the currency board were abandoned, this would also reward the speculators - hence, the "double play". The Hong Kong authorities' response was to retaliate against the

[3]See Blustein (2001) for a popular account of the controversies surrounding the role of the IMF in the late 1990s. The academic literature has also drawn attention to the possibility that emerging market crises take on the nature of liquidity crises. See, for instance, Chang and Velasco (1999).

speculators by pushing them into a short squeeze. Goodhart and Lu (2003) have written a very vivid account of this episode.

The purpose of our paper is to construct a simple, yet flexible analytical framework that can explain the internal dynamics of twin crises, and trace the effects of monetary policy on market aggregates. We also attempt to identify the appropriate policy response in anticipation of a crisis, in particular when higher interest rates are appropriate (and when they are not appropriate).

The key feature of our framework is the feedback role of market prices in a crisis - in particular, how the exchange rate and asset prices interact in distress situations. Market prices not only convey information about the underlying fundamentals, but they also determine the actions of market participants. In extreme cases, there is often little discretion in the actions of market participants. As such, market prices also dictate actions, thereby completing the circle of prices to actions to back to prices. In understanding the dynamics of crises, it is important to recognize the potential for how this circle can generate amplified responses in which distress feeds on itself. One of our main goals will be to construct a framework that brings this endogenous response out clearly.

The feedback role of market prices has been well-recognized in the literature on so-called "liquidity black holes". Even in mature financial markets there are episodes of turbulence of such an extreme kind that markets appear to stop functioning altogether. Such episodes are marked by a heavily one-sided order flow, rapid price changes, and financial distress on the part of many of the traders. The 1987 stock market crash is perhaps the most glaring example of such an episode, but there are other, more recent examples such as the collapse of the dollar against the yen on October 7th, 1998, and instances of distressed trading in some fixed income markets during the

LTCM crisis in the summer of 1998. Practitioners dub such episodes "liquidity holes" or, more dramatically, "liquidity black holes" (Taleb (1997, pp. 68-9), Persaud (2001)). Morris and Shin (2004a) construct a formal model of this phenomenon.

Liquidity black holes are not simply instances of large price changes. Public announcements of important macroeconomic statistics, such as the U.S. employment report or GDP growth estimates, are sometimes marked by large, discrete price changes at the time of announcement. However, such price changes are arguably the signs of a smoothly functioning market that is able to incorporate new information quickly. The market typically finds composure quite rapidly after such discrete price changes, as shown by Fleming and Remolona (1999) for the US Treasury securities market.

In contrast, liquidity black holes have the feature that they seem to gather momentum from the endogenous responses of the market participants themselves. Rather like a tropical storm, they appear to gather more energy as they develop. Part of the explanation for the endogenous feedback mechanism lies in the idea that the incentives facing traders undergo changes when prices change. Market distress can feed on itself. When asset prices fall, some traders may get close to their loss limits and are induced to sell. But this selling pressure sets off further downward pressure on asset prices, which induces a further round of selling, and so on. Portfolio insurance based on dynamic hedging rules is perhaps the best-known example of such feedback, but similar forces will operate whenever traders face constraints on their behaviour that shorten their decision horizons. Daily loss limits and other controls on traders' discretion arise as a response to agency problems within a financial institution, and are there for good reason. However, they have the effect of shortening the decision horizons of the traders.

The price feedback effect in a twin crisis can be seen as a more elaborate version of the liquidity black hole phenomenon. Rather than operating through just one price, the feedback loop in the twin crisis operates through two prices - the domestic asset price, and the exchange rate. Marking to market of the dollar liabilities and the domestic assets (or the collateral assets underpinning loans) completes the loop. The fact that the feedback loop runs through two prices rather than one makes twin crises much more potent. As domestic banks dispose of assets in order to repay their dollar loans, the size of the sales must increase for two reasons - both due to the fall in the value of the domestic assets in domestic prices, but also through the fall in the value of the domestic currency against the dollar. One of our primary goals will be to outline the mechanisms involved in this process.

The outline of our paper is as follows. We begin in the next section with a closed economy framework that highlights the role of prices in amplifying the effect of shocks to a banking system. We then proceed to present our main model of a banking system in an open economy setting in which foreign creditor banks interact with the domestic banking system. The foreign creditor banks mark their assets to market in dollar terms, and hence both the domestic asset price (in local currency terms) and the exchange rate enter into the analysis. Marking to market then implies that these two prices are intimately linked in the crisis dynamics. We conclude the paper with some reflections on the interpreation of our framework and directions for future research.

2 Framework for Closed Economy

We begin with a closed economy setting that will form the basis of our main open economy model. There are two main elements of the framework -

the domestic financial system consisting of n domestic banks, and the group of foreign lenders who supply dollar credit to the domestic banking system. In order to identify the main questions for the general model, it is useful to consider the model that arises in a closed economy. The following description draws on the working paper by Cifuentes, Ferrucci and Shin (2003).

2.1 Banking System in a Closed Economy

There are n interlinked banks in the domestic banking system. The notional liability of bank i to bank j is denoted by L_{ij}. The total notional liability of bank i is then the sum

$$\bar{x}_i \equiv \sum_j L_{ij}$$

Denote by x_i the marked-to-market value of bank i's liability to all other banks in the system. Banks have equal seniority in interbank claims. Thus, defining $\pi_{ij} = L_{ij}/\bar{x}_i$, the market value of bank j's claim on bank i is given by

$$x_i \pi_{ij} \tag{1}$$

while the market value of bank i's claim on all other banks is

$$\sum_j x_j \pi_{ji}$$

Banks also have illiquid assets, such as loans to corporates. In the model, we will assume that there is a single type of illiquid asset. Bank i's holding of the illiquid asset is given by e_i. The price of the illiquid asset is denoted by p. Although loans are typically not marked to market, the collateral assets for the loan will be marked to market. By assuming that all loans are collateralized, we will speak of the illiquid asset having the market value p.

In addition to the illiquid asset, bank i has holdings of a liquid asset such as short term government bonds. The price of the liquid asset is fixed at

1. Denote by c_i the amount of the liquid asset held by bank i. Thus, the marked-to-market *net worth* or *equity value* of bank i is

$$pe_i + c_i + \sum_j x_j \pi_{ji} - x_i$$

Limited liability of the bank implies that its equity value is non-negative. Priority of debt over equity implies that equity value is strictly positive only when $x_i = \bar{x}_i$ (i.e.) the market value of bank i's liability is equal to its notional liability. Thus, the vector $x = (x_1, x_2, \cdots, x_n)$ is such that for each i,

$$x_i = \min \left\{ \bar{x}_i,\ w_i(p) + \sum_j x_j \pi_{ji} \right\} \tag{2}$$

where $w_i(p) = pe_i + c_i$ is the marked-to-market value of the liquid and illiquid assets of bank i. More succinctly, we can write (2) in vector form as

$$x = \bar{x} \wedge \left(w(p) + \Pi^T x \right) \tag{3}$$

where $w(p) = (w_1(p), \cdots, w_n(p))$, Π^T is the transpose of the exposure matrix Π, and $\wedge$ is the pointwise minimum operator. Thus, a clearing vector x that satisfies (3) is a fixed point of the mapping

$$H(x) \equiv \bar{x} \wedge \left(w(p) + \Pi^T x \right)$$

$H(.)$ is an increasing function on the lattice $\mathbb{R}^n_+$ (with infimum defined by the operator $\wedge$), and where $H(0) \geq 0$ and $H(\bar{x}) \leq \bar{x}$. The lattice is also complete when restricted to the set $\times_{i=1}^n [0, \bar{x}_i]$. Hence, by Tarski's fixed point theorem, there is at least one fixed point of $H(.)$, and hence at least one clearing vector x. Eisenberg and Noe (2001) have proved that under mild regularity conditions, there is a unique fixed point of such a function. A sufficient condition for the existence of a unique fixed point is that, first, the

system is *connected* in the sense that the banks cannot be partitioned into two or more unconnected sub-systems, and that there is at least one bank that has positive equity value in the system. By drawing on the results of Eisenberg and Noe, we can proceed as follows. For any fixed value of p, the the net worth of each bank is determined fully. Hence, by appealing to the result of Eisenberg and Noe (2001), we have the following lemma.

Lemma 1 *Suppose the banking system is connected, and that at price p, there is at least one bank that has positive equity value. Then, there is a unique clearing vector x such that*

$$x = \bar{x} \wedge \left(w\left(p\right) + \Pi^T x \right)$$

Let us write $x\left(p\right)$ to be the unique clearing vector when the price of the illiquid asset is given by p. Then x_{ij} is determined by the pro rata rule (1). Hence, this lemma allows us to write each x_{ij} as a function of p. We will use this feature in what follows.

2.2 Endogenous Financial Distress

The domestic banks are subject to a capital adequacy constraint, which stipulates that the ratio of the bank's equity value to the marked-to-market value of its assets must be above some pre-specified ratio r^*. When a bank finds itself violating this constraint, it must sell some of its assets so as to reduce the size of its balance sheet. Denote by t_i the units of the liquid asset sold by bank i, and denote by s_i the units of the illiquid asset sold by bank i.

The capital adequacy constraint puts a lower bound on the capital asset ratio of the bank. The constraint is given by

$$\frac{pe_i + c_i + \sum_j x_j \pi_{ji} - x_i}{p\left(e_i - s_i\right) + \left(c_i - t_i\right) + \sum_j x_j \pi_{ji}} \geq r^* \tag{4}$$

The numerator is the equity value of the bank where the interbank claims and liabilities are calculated in terms of their market values. The denominator is the marked-to-market value of its assets after the sale of s_i units of the illiquid asset and sale t_i of the liquid asset. The underlying assumption is that the assets are sold for cash, and that cash does not attract a capital requirement. Thus, if the bank sells s_i units of the illiquid asset, then it has ps_i in cash, and holds $p(e_i - s_i)$ worth of the illiquid asset. Hence, we have the sum of these (given by pe_i) on the numerator, while we have only the mark to market value of the illiquid asset (given by $p(e_i - s_i)$) on the denominator. Similar remarks apply to the liquid asset. Thus, by selling its assets for cash, the bank can reduce the size of its balance sheet and hence reduce the denominator, making the capital asset ratio larger.

We make two assumptions. First, the bank cannot short sell the assets. Thus,

$$s_i \in [0, e_i] \quad \text{and} \quad t_i \in [0, c_i]$$

Second, we assume that the bank sells all its liquid assets before it starts selling its illiquid assets. Thus, $s_i > 0$ only if $t_i = c_i$. Any value maximizing bank will follow this rule, and hence this assumption is not a strong one.

An equilibrium is the triple (x, s, p) consisting of a vector of payments x, vector of sales of illiquid asset s, and the price p of the illiquid asset such that:

1. For all banks i, $x_i = \min\left\{\bar{x}_i,\ pe_i + c_i + \sum_j x_j \pi_{ji}\right\}$
2. For all banks i, s_i is the smallest sale that ensures that the capital adequacy condition is satisfied. If there is no value of $s_i \in [0, e_i]$ for which the capital adequacy condition is satisfied, then $s_i = e_i$.

3. There is a downward sloping demand function $d(.)$ such that $p = d\left(\sum_i s_i\right)$.

The first clause is reiterating the limited liability of equity holders, and the priority and equal seniority of the debt holders. The second clause says that either the bank is liquidated altogether, or its sales of illiquid assets (possibly zero) reduces its assets sufficiently to comply with the capital adequacy ratio. Finally, the third clause states that the price of the illiquid asset is determined by the intersection of a downward sloping demand curve and the vertical supply curve given by aggregate sales.

By re-arranging the capital adequacy condition (4) together with the condition that s_i is positive only if $t_i = c_i$, we can write the sale s_i as a function of p, where $s_i = 0$ if the capital adequacy condition can be met by sales of the liquid asset or from no sales of assets, but otherwise is given by

$$s_i = \min\left\{ e_i,\ \frac{\sum_j x_{ij} - (1 - r^*)\left(\sum_j x_{ji} + pe_i\right) - c_i}{r^* p} \right\}$$

The value of interbank claims x_{ij} are all functions of p. Thus, s_i itself is a function of p, and we write $s_i(p)$ the sales by bank i are a function of the price p. Let

$$s(p) = \sum_i s_i(p)$$

be the aggregate sale of the illiquid asset given price p. Since each $s_i(.)$ is decreasing in p, the aggregate sale function $s(p)$ is decreasing in p.

2.3 Net Worth of the Domestic Banking System

The inverse demand curve for the illiquid asset is assumed to be

$$p = e^{-\alpha\left(\sum_i s_i\right)} \tag{5}$$

where $\alpha > 0$ is a positive constant. The maximum price is $p = 1$, which occurs when sales are zero. We impose two regularity conditions on the demand and sales functions. First, we will require that the banking system does not spiral down into zero net worth when all the illiquid assets are sold. When the entire endowment of illiquid assets in the system are sold, there is at least one bank that has positive equity value. Let $\underline{p}$ be the price of the illiquid asset when the entire endowment of the illiquid asset is sold. That is $\underline{p} = d^{-1}\left(\sum_i e_i\right)$. Our first regularity condition is

$$s\left(\underline{p}\right) < d\left(\underline{p}\right) \tag{6}$$

Our second regularity condition is at the oppposite end of the price spectrum. We require that when the price of the illiquid asset is at its highest, given by $p = 1$, no bank is forced to sell any of its illiquid assets. In other words, $s(1) = 0$. From (5), we have $d(1) = 0$. Together, we have

$$s(1) = d(1) \tag{7}$$

An equilibrium price of the illiquid asset is a price p for which

$$s(p) = d(p)$$

From (7), we have at least one equilibrium price, given by $p = 1$. This is the status quo price where the banking system has not suffered any adverse shock. However, an equilibrium price lower than 1 is possible provided that the $s(p)$ curve lies above the $d(p)$ curve for some ranges of price (see figure 1).

The price adjustment process can be depicted as a step adjustment process in the arc below the $s(p)$ curve, but above the $d(p)$ curve. The process starts

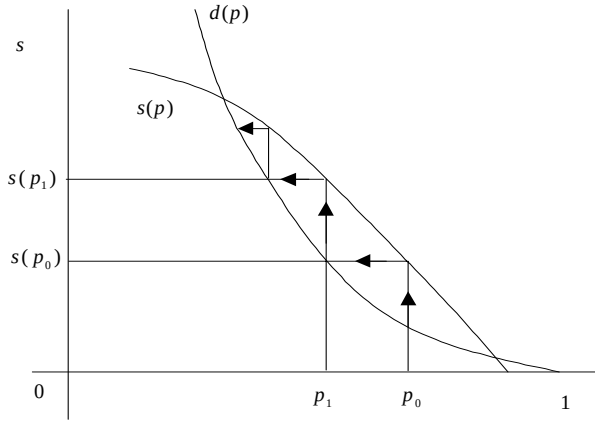

Figure 1:

with a downward shock to the price of the illiquid asset. At the lower price p_0, the forced sales of the banks puts quantity $s(p_0)$ on the market. However, this pushes the price further down to $p_1 = d^{-1}(s(p_0))$. This elicits further selling, implying total supply of $s(p_1)$. Given this increased supply, the price falls further to $p_2 = d^{-1}(s(p_1))$, and so on. The price falls until we get to the nearest intersection point where the $d(p)$ curve and $s(p)$ curve cross.

Equivalently, we may define the function $\Phi : [\underline{p}, 1] \to [\underline{p}, 1]$ as

$$\Phi(p) = d^{-1}(s(p))$$

and an equilibrium price is a fixed point of the mapping $\Phi(.)$. The function $\Phi(.)$ has the following interpretation. For any given price p, the value $\Phi(p)$ is the market-clearing price of the illiquid asset that results when the price of the illiquid asset on the banks' balance sheets are evaluated at price p. Thus, when $\Phi(p) < p$, we have the precondition for a downward spiral in

the illiquid asset's price. The price that results from the sales is lower than the price at which the balance sheets are evaulated. We can summarize our results as follows.

Proposition 2 *If $\Phi(p) \geq p$ for all p, there is a unique equilibrium in which $p = 1$. In this case, the value of the banking system declines only by the size of the initial shock.*

Proposition 3 *If $\Phi(p) < p$ for some values of p, then there is an equilibrium in which p is strictly below 1, and in which there are sales of the illiquid asset. In this case, the banking system will reach this equilbrium by the step adjustment process provided that the initial shock is big enough.*

The first proposition is immediate. Thus, when the $\Phi(p)$ curve lies above the 45 degree line, there is no endogenous fall in the asset value of the banking system. The only effect of the initial shock is to reduce the banking sector's value by the amount of the initial shock. The second proposition follows from the continuity of the $\Phi(.)$ mapping, which inherits its continuity from the continuity of $d(p)$ and $s(p)$. In this case, there is an amplification effect that arises from the endogenous responses generated by the forced sales.

2.4 Prices in an Open Economy

The simple analytical device sketched above can serve as the motivation for an analysis of the open economy extension. Given the equilibrium price p of the illiquid asset, the net worth of the domestic banking system can be derived as the sum of the marked-to-market value of the total illiquid asset holdings and the liquid asset holdings. In domestic currency terms, the net worth of the banking system (in local currency terms) is given by

$$W(p) = \sum_i (p\bar{x}_i + c_i)$$

where $\bar{x}_i$ is the total holding of the illiquid asset by domestic bank i, and c_i is bank i's holding of the liquid asset. Foreign lenders who supply dollar credit to the domestic banking system will compare the dollar value of the liabilities with the dollar value of the domestic assets. Let e be the dollar exchange rate which gives the number of dollars per unit of the domestic currency. Thus, a high e corresponds to a strong local currency. Then, the dollar value of the net worth of the domestic banking system is given by

$$V \equiv e \cdot W(p)$$

Denote by D the dollar value of the loans made by foreign lenders to the domestic banking system. Then, the decision of the foreign lenders can be defined in terms of pair

$$(V, D)$$

where the supply of dollar credit to the domestic banking sector is increasing in $eW(p)$, but decreasing in D. The decision rule of the foreign banks can be rationalized in terms of the credit risk models used by these banks, or calculations of economic capital. Game theoretic foundations in terms of individual creditors' decisions could also be given in terms of the global game framework (see Morris and Shin (2003, 2004b) for details).

In the extended model, there are now two prices that are relevant - p and e. Denote by

$$F(p, e)$$

the price of the illiquid asset that results from the sales of the illiquid asset when the balance sheets of the domestic banks are evaluated at the price p, and the foreign banks make their credit decisions based on the pair (V, D). The function F is decreasing in both p and e. The intuition is as follows. When p falls, the capital adequacy constraint of the domestic banks force

them to sell more of the asset, leading to a fall in the price of the illiquid asset. When e falls, the dollar value of the net worth of the domestic banking system falls, so that foreign lenders withdraw dollar credit. This entails forced sales of the illiquid asset by the domestic banks, since the size of their balance sheets must be reduced by the magnitude of the decline in dollar credit.

Turning now to the exchange rate, denote by

$$G(p, e)$$

the value of the exchange rate (dollars per unit of domestic currency) when the foreign banks are faced with prices p and e. The function G is decreasing in both p and e. When p falls, the dollar value of the net worth of the domestic banking system falls, leading to withdrawal of credit by the foreign banks and sales of the domestic currency in favour of dollars. When e falls, the net worth of the domestic banking system falls, also. This causes an outflow of dollars, leading to a depreciation of the domestic currency (fall in e).

Taking the functions F and G together, we can define a mapping Φ from the pair (p, e) to another pair (p', e') where

$$\Phi(p, e) = (F(p, e), G(p, e))$$

An equilibrium in the open economy version of the model is defined as a fixed point of the mapping Φ. Just as in the closed economy model, our framework can accommodate the effect of endogenous financial distress, in which a fall in p or e may be amplified through the interaction between the sales of illiquid assets and the withdrawal of credit by the foreign lenders.

3 Open Economy Extension

In order to address the issue of the twin crisis, we will now extend our model to an open economy setting. Thus, in addition to the domestic banks, we introduce a set of foreign creditor banks. However, we also attempt to keep the analysis as simple as possible by imposing particular balance sheet structures to the domestic and foreign creditor banks. The balance sheets are stylized representations of the financial crisis of 1997 in Korea. The model departs in significant ways from the actual institutional arrangements in Korea, but the aggregate effects are preserved. The reader is referred to Hahm (2000) and Hahm and Shin (2002) for a more complete description of the institutional backdrop to the Korean crisis.

One of the key features of the 1997 crisis was the currency mismatch on the balance sheets of many Korean financial institutions. By borrowing at the (low) dollar rates, but investing in high-yielding assets, both in Korea and elsewhere in Asia, the banks were betting on being able to reap the benefits of the yield differential between dollars and Asian currencies. As long as the currency peg held, this strategy was profitable.

However, with exchange rate risk, it is the uncertainty over the banks' fluctuating liabilities that becomes pivotal. If the Korean bank has borrowed short term in dollars, there is uncertainty as to whether the foreign lenders will roll over the dollar loans to the Korean banks. In other words, there is uncertainty over the *liabilities side* of the balance sheet of the Korean banks. If the foreign banks react to weakening fundamentals by refusing to roll over the dollar loans to the Korean banks, then the funding for the Korean banks' "dollar carry" strategy becomes undermined. As dollar liabilities become due, assets held by the Korean banks must be sold or liquidated in order to repay the foreign lenders. Assets that are disposed are domestic marketable

assets or loans to local borrowers. Thus, the refusal of foreign lenders to roll over loans has two immediate effects.

- Domestic assets are sold by the Korean banks. As such sales take place, domestic asset prices fall.
- Since repayments must be made to foreign lenders in Dollars, the Won is bid down relative to the Dollar. There is a general depreciation of the Won.

Both these effects have the consequence that the dollar value of the Korean banking system declines. Foreign lenders will view this developments with concern. The decline in net worth of the banking system represents a deterioration of the credit quality of the Korean borrowers. Prudent risk control belatedly reasserts itself in the decision making of the foreign creditor banks, and they become reluctant to roll over their dollar loans to the domestic banking system. This weakens the balance sheet positions of the domestic banks still further, inducing further sales of domestic assets. The repatriation of funds weakens the domestic currency further, fuelling the vicious circle.

The simple analytical framework presented here attempts to capture the mutually reinforcing effect of depreciation of the Won and the fall in domestic asset prices. There are two sets of banks in the model - the local Korean banks and the foreign, creditor banks.

A Korean bank holds one unit of an illiquid asset that has price p, and funds this asset by borrowing in dollars from foreign creditor banks. This asset is indivisible, so that the Korean bank can either hold one unit of it, or none at all. The Korean bank borrows D in dollar terms. We denote by e the price of Won in terms of dollars. Hence high e corresponds to a

strong Won, and low e corresponds to a weak Won. In local currency terms, therefore, the Korean bank has liabilities of D/e. The simplified balance sheet of a Korean bank (denominated in Won) is given as follows.

Korean Bank's B/S (in Won)

Assets	Liabilities
p	D/e

We will suppose that the asset on the Korean bank's balance sheet is marked to market. This is without loss of generality for our purposes. For assets such as loans (which are not normally marked to market), the collateral assets will nevertheless be marked to market. Fluctuations in the price of the collateral asset will have very similar effects to the effects examined in this paper.

There are many foreign creditor banks, indexed by i. The asset side of the foreign creditor bank's balance sheet consists of the dollar loan D to the Korean bank. The foreign creditor banks have identical liabilities L. The stylized balance sheet of the foreign creditor bank (denominated in dollars) is thus given as follows.

Foreign Bank's B/S (in Dollars)

Assets	Liabilities
D	L

The foreign banks monitor the performance of their loans by keeping track of the equity value of the Korean banks to whom they have lent. Their decision to roll over their loans to the Korean banks depends on the net worth of the Korean banks. We will impose a particularly simple decision rule on the foreign banks. Foreign bank i rolls over its loan to the Korean

bank provided that the net worth of the Korean bank is greater than some fixed threshold value ρ_i. Thus, foreign bank i rolls over the loan provided that

$$pe - D \geq \rho_i \tag{8}$$

The left hand side of this inequality is the marked to market dollar value of the net worth of a Korean bank. The roll over decision of the foreign creditor banks assumed in this paper is motivated by the tightening credit risk control in the face of deteriorating circumstances of the borrower. When faced with other creditor banks who face similar decisions, the coordination motive to pull credit lines could arguably be even stronger. See Morris and Shin (2004b) for a model of creditor coordination.

We will suppose that the constants ρ_i are uniformly distributed over the interval $\left[\underline{\rho}, \bar{\rho}\right]$. The differences in the threshold constants ρ_i reflect other items from the foreign banks' balance sheets that we have abstracted from. Denote by f the proportion of foreign creditors who refuse to roll over ("f" stands for "foreclosure"). Given the roll-over rule (8), the proportion of foreign banks who refuse to roll over their loans can be depicted as in figure 2. The downward-sloping portion of the foreclosure curve in figure 2 is linear, and thus we let f be the linear function $a - kpe$ for positive constants a and k for this portion of the foreclosure curve.

Meanwhile, a Korean bank has limited discretion when the foreign creditor bank refuses to roll over the short term dollar loan. The illiquid asset is indivisible, and hence the Korean bank must sell the illiquid asset in order to meet the repayment to the foreign creditor bank. Given foreclosure of f foreign creditors, total sales s must be such that this raises enough dollar revenue to repay the foreign creditor banks. Denote by s the total sale of the illiquid asset by the domestic banking system due to the foreclosure decision

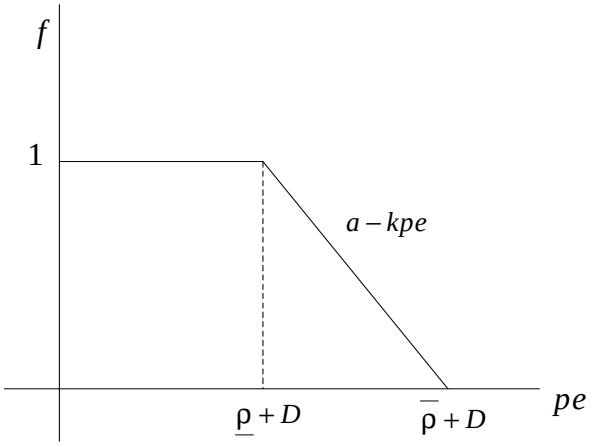

Figure 2:

of the foreign creditor banks, and let $\bar{x}$ be the total holding of the illiquid asset by the domestic banking system. The Won value of sales is ps, while the total dollar value of the sales is $ps \cdot e$. Then from (8), total sales s satisfies

$$s = \begin{cases} 0 & \text{if } pe > \bar{\rho} + D \\ f/pe & \text{if } \frac{f}{pe} < \bar{x} \text{ and } pe < \underline{\rho} + D \\ \bar{x} & \text{otherwise} \end{cases} \tag{9}$$

Thus, the total sale of domestic assets is dictated by the dollar value of the illiquid asset holding over the (dollar) liabilities to foreign creditor banks.

There is a domestic market for the illiquid asset, and the equilibrium price of the asset is determined within this market. The demand curve for the asset is downward sloping, and we assume that the demand is linear, given by

$$p = \bar{p} - bs \tag{10}$$

Thus, if there are no foreclosures by the foreign creditor banks (so that

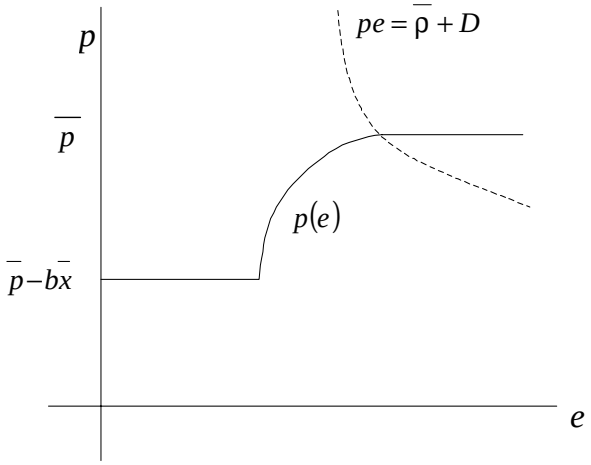

Figure 3:

$s = 0$), then the equilibrium price of the asset is $\bar{p}$. This is the price in Won. However, if sales are non-zero due to the foreclosure of the foreign banks, then equilibrium price will be lower than $\bar{p}$. Substituting the sales equation (9) into the demand equation (10), we can derive a relationship between the exchange rate e and the domestic price p of the illiquid asset.

$$p = \begin{cases} \bar{p} & \text{if } pe > \bar{\rho} + D \\ \bar{p} - b\left(\frac{a}{pe} - k\right) & \text{if } \frac{f}{pe} < \bar{x} \text{ and } pe < \underline{\rho} + D \\ \bar{p} - b\bar{x} & \text{otherwise} \end{cases} \tag{11}$$

where the constants a and k are the parameters from figure 2. We can depict the above relationship in figure 3. The price p of the illiquid asset is a function of the exchange rate e. In the region where pe is high, in particular, when $pe \geq \bar{\rho} + D$, there is no foreclosure by the foreign creditor banks, and hence $s = 0$. Thus, $p = \bar{p}$. As the value of the Won falls,

the dollar value of the illiquid asset held by the Korean bank falls, and this triggers foreclosure by the foreign creditor banks. The foreclosures force the Korean banks to sell the illiquid asset, and the price falls due to the sales. As e falls further, the foreclosures become larger, and the sales of the illiquid asset become larger.

Notice that the increased sale of the illiquid asset is more than proportional to the (dollar) foreclosure of the creditor banks. This is because, as the exchange rate depreciates, a greater amount of the domestic asset must be sold in order to raise the same amount of dollars. Thus, there is a "double whammy". As the exchange rate depreciates, not only is there a greater incidence of foreclosure, but more of the asset must be sold. Thus, the price decline of the illiquid asset accelerates as the exchange rate falls. This accounts for the locally concave shape of the $p(e)$ curve in figure 3. The price decline will continue until all the asset holdings of the domestic banking system is sold on the market. This happens when supply reaches $s = \bar{x}$. From that point onwards, the price stabilizes at $p = \bar{p} - b\bar{x}$. In figure 3, this is represented by the flat portion of the $p(e)$ curve for low values of e.

Equation (11) links the exchange rate e with the asset price p. Meanwhile, from the equilibrium condition in the foreign exchange market, we obtain another equation that links e and p. The Won exchange rate e is a decreasing function of the short term sales of Won (and purchase of dollars) that arises from the foreclosure decision of the foreign creditor bank. We do not model the long-run portfolio decision directly, but adopt the view that the short-run exchange rate is influenced by the order flows in the foreign exchange market, as argued by Lyons (2001) and Evans and Lyons (2002). For simplicity, we adopt the linear short-run demand curve

$$e = \bar{e} - \lambda f$$

where $\bar{e}$ is a constant that represents the exchange rate in the absence of any Won sales resulting from foreclosures by the foreign creditor banks. The parameter $\lambda > 0$ represents the degree of short-run illiquidity in the foreign exchange market. When λ is large, even a small amount of Won sales will depress the exchange rate. Since foreclosure f is determined by the roll-over rule (8), we can derive a relationship between the exchange rate e and asset price p as follows.

$$e = \begin{cases} \bar{e} & \text{if } pe > \bar{\rho} + D \\ \frac{\bar{e} - \lambda a}{1 - \lambda k p} & \text{if } \frac{f}{pe} < \bar{x} \text{ and } pe < \underline{\rho} + D \\ \bar{e} - \lambda & \text{otherwise} \end{cases} \tag{12}$$

Equations (11) and (12) give two questions that link the exchange rate e with the asset price p. Equation (11) arises as the equilibrium condition in the market for the illiquid asset (in local currency terms), while equation (12) arises from equilibrium in the foreign exchange market. We can plot both equations simultaneously in (p, e)-space by defining the curve $g(p)$ as the inverse of the $p(e)$ mapping:

$$g(p) \equiv p^{-1}(p)$$

Figure 4 depicts the determination of the equilibrium e and p as the intersection of the $g(p)$ and $e(p)$ curves. Notice that the equilibrium is stable in a step-wise adjustment sense. Suppose that the asset price falls below the equilibrium point due to an exogenous shock. Then the exchange rate consistent with the new asset price is determined by the $e(p)$ curve. This is indicated by the lowest arrow in figure 4. Given an exchange rate e, the asset price that is consistent with this exchange rate is given by the $p(e)$ function. In figure 4, this is depicted by the horizontal arrow that maps the

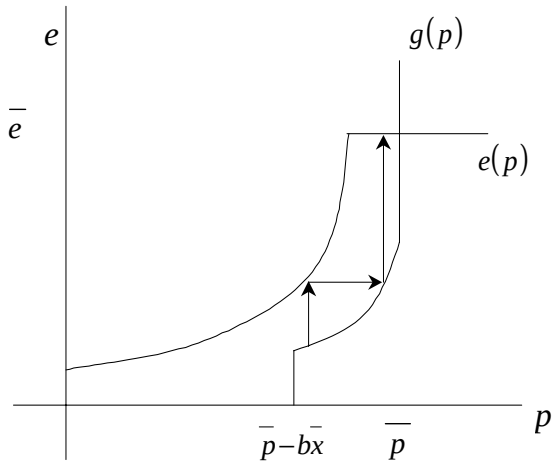

Figure 4:

exchange rate to the $g(p)$ curve, that gives the asset price consistent with the new exchange rate. The step-wise adjustment carries on in this way, until the system returns to the initial equilibrium at the intersection between $g(p)$ and $e(p)$.

In contrast to the optimstic adjustment scenario depicted in figure 4, it is also possible that the equilibrium of the system corresponds to a distress situation in which a low asset price induces further selling, which both depresses the exchange rate and further depresses the asset price. This more pessimistic scenario is depicted in figure 5. Here, the intersection between the two curves lies in the distress region in which both the value of the currency and the asset price are low. The fact that both curves are upward-sloping means that the intersection point can be in the distress region. Notice also that the equilibrium identified in figure 5 is stable in the step-wise adjustment sense, and that this adjustment can be seen as the "downward spiral"

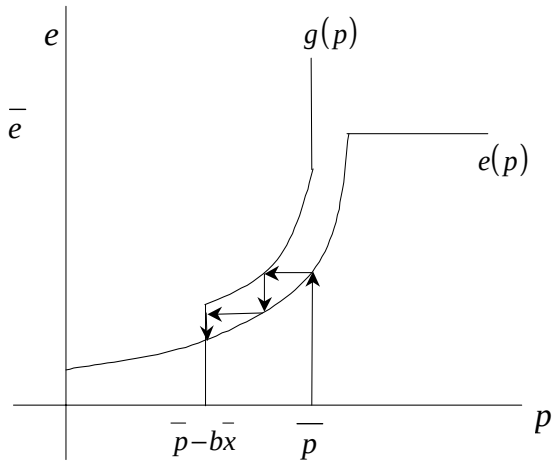

Figure 5:

in which asset price falls and exchange rate depreciation reinforce each other. In figure 5, the high asset price $\bar{p}$ is not sustainable. The exchange rate consistent with $\bar{p}$ is given by $e(\bar{p})$, but this exchange rate is only consistent with a strictly lower asset price (depicted by the horizontal arrow leftwards). In turn, the lower price sets off a further depreciation, which in turn depresses the asset price further. This "downward spiral" takes the economy to the intersection point in the bottom left region, representing collapsed asset prices and a very low exchange rate.

4 Monetary Policy in a Crisis

The framework sketched above can be used to address the policy question of the appropriate stance of monetary policy in a twin crisis. In the simplest setting, we can identify the policy question with the comparative statics

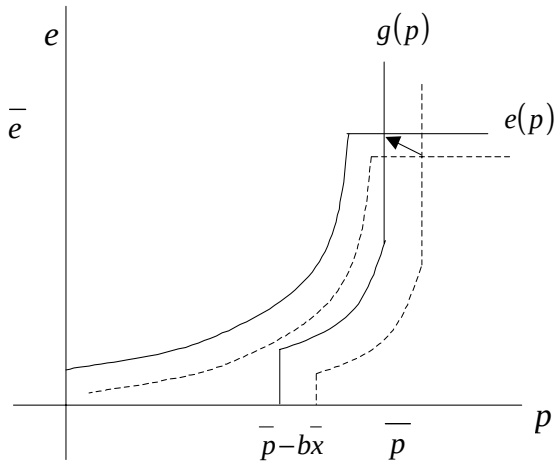

Figure 6:

question of what happens as a consequence of a shift in interest rates. During the financial crisis of 1997, the policy prescription for Korea from the IMF was to tighten monetary policy, raising interest rates substantially. The rationale for this policy was that the increase in interest rates would ease the pressure on the exchange rate (both by making it more costly for speculators to attack the currency, and also to increase the attractiveness of holding Korean Won). There would also be undesirable knock-on effects in terms of a fall in asset prices, but this was judged to be the lesser of two evils.

The reasoning inherent in this argument can be depicted in terms of figure 6. An increase in interest rates shifts the $g(p)$ curve to the left and the $e(p)$ curve upwards. This is because the interest rate increase lowers asset prices, but raises the short-run demand for Won in the foreign exchange market. The resulting shift in equilibrium is depicted by the arrow in figure 6. While the asset price falls, the value of the currency rises.

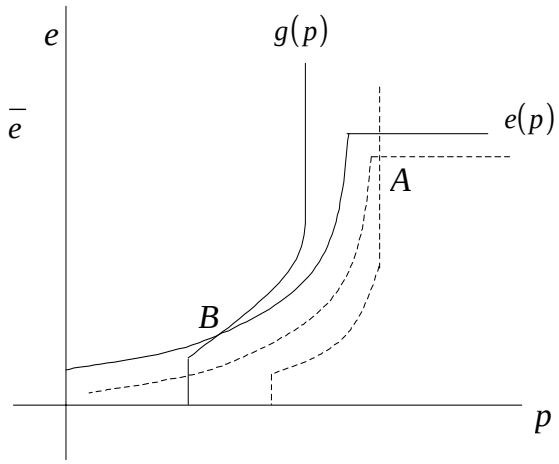

Figure 7:

However, contrary to the optimistic scenario painted above, an increase in interest rates can have the opposite effect of leading to a collapse of the exchange rate, and a collapse of the domestic asset market. This alternative scenario is shown in figure 7. When the negative shock to the asset market that results from the rise in interest rates is severe, the shift of the $g(p)$ curve can take it to the region where the new equilibrium corresponds to the distress outcome. In figure 7, both the $e(p)$ curve and the $g(p)$ curve has shifted so that the new equilibrium point is given by point B. The initial equilibrium point was A. Thus, the increase in the interest rate kicks off a cycle of decline that ends up causing substantial falls both in the asset price and the value of the currency. Thus, far from defending the exchange rate, the interest rate rise will lead to the collapse of the exchange rate.

Our analysis highlights the importance of the sensitivity of the asset price to the exchange rate and interest rate. These sensitivities can be discussed

along several dimensions. The appropriate response of monetary policy to a crisis depends on the following factors.

- How illiquid and interest-rate sensitive are the assets held by the domestic banking sector? In general, the larger the more illiquid is the asset, and the more interest rate sensitive is the asset, the greater will be impact of a rise in interest rates, and the greater will be the feedback effect in which asset price falls lead to further distressed sales of the asset. Real estate is the classic case of an asset that is both highly illiquid, and also of long duration.

- How severe is the currency mismatch on the balance sheets of the domestic banks? The greater is the currency mismatch, the more sensitive will be the price of the domestic assets to shifts in the exchange rate.

- How much capital does the domestic banking system carry? When domestic banks are well-capitalised, small fluctuations in the asset price will not lead to distressed selling, and hence the net worth of the domestic banking system will be sufficiently high that the foreign lenders will not foreclose on their loans. In turn, this will mean that the domestic asset price will be less sensitive to the exchange rate.

- What is the capacity of the economy as a whole to absorb distressed sales of assets? When distressed sales can be absorbed by other potential users of the assets, then the vicious circle in which asset price falls lead to further distressed selling can be curtailed.

- How much discretion does the central bank have in supplying liquidity in crisis situations? This question is related to the one above on how

much of the distressed sales of assets can be absorbed. If the central bank can extend its lender of last resort activities by expanding the set of eligible securities in its repo operations, price falls can be cushioned by this additional demand.

Underlying the liquidity black hole that drives the twin crisis is the feedback from prices to outcomes, back to prices. Marking to market of the dollar liabilities and the domestic assets (or the collateral assets for loans) is key. The marking to market of liabilities and assets transmits the price shocks straight through to the balance sheets of the financial institutions. Therefore, the underlying accounting regime is likely to play an important role in the transmission of shocks. Mark-to-market accounting will exacerbate the twin crisis once it is in motion. This, of course, does not imply that marking to market is undesirable as a policy issue. The increased transparency afforded by marking to market will have many ex ante incentive effects that are beneficial. The claim is merely that, once the crisis has been set in motion, the increased transparency of prices will exacerbate the speed and depth of the crisis.

5 Regulation and Policy Response

We are now in a position to draw together the strands in our discussion and comment on the policy significance. There are two dimensions to policies - *ex ante* policies aimed at preventing crises or mitigating their effects, and *ex post* crisis management policies.

In the exercise in the previous section, we looked at the *ex post* stability effects of marking to market in an open economy setting for banks with exogenous portfolios. Because financial institutions do not internalise the

externalities of network membership, banks' liquidity choices will be sub-optimal. As a consequence, liquidity and capital requirements need to be imposed externally, and should be set in relation to a bank's contribution to systemic risk, rather than on the basis of the bank's idiosyncratic risk.

One message that emerges from our analysis is that liquidity buffers may play a role similar to capital buffers. In some circumstances, liquidity requirements may be more effective than capital buffers in forestalling systemic effects. When the residual demand curve is extremely inelastic (such as during periods of major financial distress when risk appetite is very low), even a large capital buffer may be insufficient to prevent contagion, since the price impact of sales into a falling market would be very high. To put it another way, even a large capital cushion may be insufficient if the stuffing in the cushion turns out to be useless. Liquidity requirements can internalize some of the externalities that are generated by the price impact of selling into a falling market.

It is worth noting that the development of risk management systems at the level of the individual financial institution may not solve system risk. The adoption of explicit risk management techniques has been accompanied by a growing acceptance by regulators of self-policing by the financial institutions themselves using their own internal risk management models. This growing acceptance means that it is more important than ever to get things right. What's at issue is whether such bouts of turbulence will subside as more sophisticated versions current risk management techniques become more widely adopted, or whether the more widespread adoption of such techniques merely serve to increase the fragility of the system. As long as the world view underlying the risk management models discounts the feedback effect from actions to outcomes, the building blocks underlying such models

remain suspect. If the externalities generated by one traders actions on the payoff distribution of another is not taken into account, then assumptions supporting a model may be undermined.

The term "externality" is a used advisedly. The usual context in which this notion appears in economics is in welfare economics - as applied to environmental issues - in which the absence of markets generates inefficient outcomes among market participants. Thus, when I take my car out on to the congested roads, I am contributing to the congestion, but this added inconvenience to others is not priced by the market, as there is no market for unencumbered use of the road. There is an analogy with the trading decisions of market participants. When one hedge fund decides to engage in the yen carry trade, the decision is based on the profitability for that trader alone. However, by short-selling the yen, this trader generates an externality for all other market participants who are engaged in the same trade in that when the yen begins to rise, its rise will be that much more accentuated by the belated attempt to cover the short yen position by this trader. Thus, just as a driver discounts the inconvenience caused by his own driving on the welfare of other drivers, the hedge fund discounts the possible losses inflicted on other market participants by his own trades.

Externalities justify a role for the regulator, whether it be in reducing congestion on the roads, or in reducing the damaging effects of market turbulence. This role can be justified even though the individual decision makers are perfectly rational, and are able to take informed decisions themselves. The incentives for individuals, whether they be individual drivers or traders, do not always take into account the effect of their decisions on others' welfare.

Crisis management poses difficult dilemmas for policy. One of the most difficult policy questions for the monetary authorities facing a twin crisis -

the combination of a currency crisis with a banking crisis - is how to conduct monetary policy in the face of the crisis. On the one hand, tightening monetary policy, by raising domestic interest rates reduces the value of the dollar liabilities on the banks' balance sheets. Also, higher domestic interest rates (other things being equal) induce the foreign lenders to roll over their loans to the domestic banks. Both of these effects would tend to mitigate the severity of the financial crisis. During the Asian crisis of 1997, the policy prescription of the IMF was to conduct tight monetary policy for these reasons.

However, there are also negative consequences of a tight monetary policy. Higher interest rates lower the value of the assets held by the banks, such as loans to corporate or household borrowers. Frequently, such loans will be collaterialized by marketable assets such as real estate, land or financial assets. As asset prices fall across the board, the credit quality of loans will deteriorate and the market value of the collateral assets will fall, inducing banks to demand more collateral or to curtail existing lending. When viewed from the outside, the net worth or equity value of the whole of the domestic banking sector will decline. Foreign lenders will then become reluctant to roll over their dollar loans to the domestic banking system, weakening the balance sheet positions of the domestic banks.

Thus, the dilemma for the monetary authorities can be stated as follows. In order to reduce the value of dollar liabilities of the banking system, interest rates must be raised. However, raising interest rates also lowers the asset value of the domestic banking system. In such circumstances, the correct monetary policy response must balance the reduction in liabilities against the reduction in asset values in the domestic banking system. The overall effect on the net worth of the domestic banking system can go either way. An

increase in interest rates could lower the net worth of the domestic banking system and thus precipitate the rush for the exits by the foreign lenders.

However, it is important to distinguish the *ex post* tools of crisis mitigation from the *ex ante* tools of crisis prevention. For instance, although the lender of last resort activity addresses *ex post* crisis mitigation, the anticipation of LOLR support will not discipline the commercial banks into reducing their foreign currency exposure on their balance sheets, or to hold more liquid, shorter duration assets that will enable them to ride out the crisis.

The *ex ante* crisis prevention dimension to policy suggests that liquidity regulation may be desirable over and above any capital requirement. Liquidity regulation in which banks are required to maintain an adequate holding of liquid assets will have the beneficial effect of cushioning the fall in asset prices. By requiring banks to hold liquid assets, the negative externality imposed by one bank through its asset sales can be mitigated. Equivalently, we may regard financial market liquidity as a *public good*. If a bank needs to readjust its portfolio, it uses up the public good of asset market liquidity. If asset markets are liquid, then a bank can readjust its portfolio without incurring losses. However, like many public goods, liquidity is under-provided if left to the decisions of individual banks. The role of regulation is to correct the market failure, and to provide the economically efficient level of liquidity. These themes are explored in more detail in Cifuentes, Ferrucci and Shin (2003).

6 Directions for future research

The analytical framework advanced in this paper suggests that the analysis of a twin crisis cannot be decomposed into the separate analysis of the

currency and banking crises. The two crises are intimately linked to each other, and serve to amplify the effect of the other crisis. The framework suggests directions for empirical work that can highlight the mechanisms in the propagation of the crisis. In the first instance, mapping the dynamics of the interaction between asset prices and the exchange rate would seem to be a promising line of inquiry. The step-wise adjustment process between p and e described above suggests that dynamic analysis that tracks the causal impact of prices and exchange rates may hold clues on the propagation of twin crises.

Twin crises are fed by the marking to market of foreign currency liabilities and domestic assets. Thus, the accounting regime in place for banks and the regulatory framework governing the calculation of bank capital and provisions will also be important in determining the vulnerabilities for the banking system. A more detailed investigation of these issues would reveal useful insights.

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