

# A Model of the Joint Distribution of Banking and Currency Crises

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## 1. Introduction

We develop a simple framework for studying the joint distribution of banking and currency crises. Previous work has examined these crises either in isolation or in perfect correlation. Our motivations for extending this work are both substantive and pedagogical. On the substantive side, we observe that both fixed exchange rates and banks collapsed during the Mexican and Asian financial crises, but in other historical periods fixed exchange rates collapsed without bank collapses or banks failed without a simultaneous collapse of the currency. The crises may be related, but they are not the same thing. We show that studying currency and bank collapses either in isolation or in perfect correlation with each other produces biased estimates of the likelihood of crises. On the pedagogical side, our framework allows us to illustrate the joint distribution of currency and banking crises in a simple picture that is the analog of one presented by Flood and Garber (1984) and used by them to study the distribution of currency crises.

Our framework builds on the early balance-of-payments crisis models of Krugman (1979) and Flood and Garber (1984) (KFG).<sup>1</sup> Those models showed that government commitments to both exchange-rate fixing and to monetizing a primary fiscal deficit inevitably produce a currency crisis. Here we discard the notion that a currency crisis is inevitable. Instead, we add to the government's fixed exchange-rate promise a second price-fixing promise involving bank deposits and we concentrate on the interaction of those promises. Our intention in this paper is to study the correlation of currency and bank collapses in a linear model that extends Flood and Garber (1984) by

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<sup>1</sup> These models build on the gold price-fixing model of Salant and Henderson (1978). We retain the spirit of these models by requiring foreign-currency reserves to be constant after a crisis.

adding risk neutral, heavily regulated banks backed by government insurance and bankruptcy laws.<sup>2</sup>

In our model, banks can accept deposits from domestic and foreign agents and invest those deposits in domestic and foreign assets. Banks may end up with a net asset or net liability position in foreign currency. Returns on domestic assets are uncertain because a shock occurs to domestic fundamentals. Returns on foreign assets--or payments on foreign liabilities--are uncertain because of exchange-rate changes. A shock to domestic fundamentals can trigger a banking collapse if it makes the return on bank investments negative, and the shock can cause a currency collapse if it makes it profitable for speculators to attack the fixed exchange rate. Banking and currency collapses can but need not occur together.

Our modeling is shaped by three important features of the Asian crisis. First, commercial banks dominated the financial systems in the Asian crisis countries. In Indonesia, commercial banks accounted for 84 percent of total assets in the financial sector at the end of 1996. In Korea, the figure was 52 percent, in Thailand, 64 percent and in the Philippines, 82 percent. (Lindgren, *et al*, 1999)

Second, when there were bank failures in the Asian crisis, depositors and creditors of financial institutions were paid off at full book value. Governments introduced blanket guarantees for depositors and creditors of financial institutions shortly after the crisis started.<sup>3</sup> They did so in order to stabilize funding for banks and prevent bank runs.<sup>4</sup>

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<sup>2</sup> We treat the degree of government insurance as a policy. Then the banking-deposit equilibrium is essentially equivalent to the fixed-exchange-rate equilibrium. Indeed, the bank is treated simply as a semi-private authority that tries to fix the price of its deposits at unity in terms of domestic currency.

<sup>3</sup> Indonesia's blanket guarantee was established after its attempt to provide a limited guarantee failed. Only the Philippines did not see the need to adopt a blanket guarantee, since it already had a well-established limited deposit insurance scheme. For the Asian crisis countries adopting blanket guarantees, the

Third, the estimated fiscal costs of restructuring financial institutions in the Asian countries dwarf the costs associated usually with balance-of-payments crises studied in isolation.<sup>5</sup> According to Lindgren *et al* (1999), the gross public sector costs associated with financial-sector restructuring will be over 45 percent of GDP in Indonesia, about 25 percent of GDP in Thailand, 15 percent in Korea and about 10 percent in Malaysia.<sup>6</sup> Initially, the costs were born mainly by central banks in the form of liquidity support to ailing banks.<sup>7</sup> Governments tried to sterilize this liquidity support, and they were largely successful in Korea and Thailand. As the situation stabilized, governments began refinancing the liquidity by issuing domestic government bonds. The full costs to the fiscal authorities will not be known for years, however, and will depend on the amount of additional losses uncovered as well as the proceeds from asset sales and re-privatization.

These three facts about the Asian crisis guide our modeling. To the KFG framework, we must add commercial banks whose depositors are well-insured. We also need to pay careful attention to the financing of financial restructuring. In the actual crisis these costs were enormous and will dominate our modeling effort.

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guarantees did not apply to shareholders and holders of subordinated debt. In Indonesia, insider deposits were not covered by the guarantee, while in Thailand, the deposits of directors and related persons were not covered unless they were shown to be at “arms length.” (Lindgren, *et al*, 1999). The blanket guarantees were announced as temporary, meant to maintain confidence during a period of restructuring. (Lindgren, *et al*, 1999).

<sup>4</sup> According to Lindgren *et al* (1999), the guarantees were effective in stabilizing banks’ domestic funding, although in some cases it took some time to gain credibility, but were less effective in stabilizing banks’ foreign funding.

<sup>5</sup> Normally, the main costs associated with balance-of-payments crises are expressed in terms of the capital gain forgone by the government on international reserve losses.

<sup>6</sup> These estimates are projections by national authorities and IMF staff. Merrill Lynch (1999) estimated recapitalization requirements for commercial banks (just one component of gross costs) at 42 percent for Indonesia, 26 percent for Thailand, 10 percent for Korea, and 11 percent for Malaysia.

<sup>7</sup> The initial liquidity support was denominated in domestic currency for all affected countries except Korea, where the Bank of Korea also provided \$23.3 billion in foreign-currency support to commercial banks. The amounts of liquidity support were especially large in Thailand and Indonesia, where the stock of support at its peak was 22 percent of GDP in Thailand and 17 percent of GDP in Indonesia. (Lindgren, *et al*, 1999).

Our results are appealing and are easily extended. Government guarantees – explicit or implicit – to possibly fragile banks or other firms undermine the fixed exchange rate. All government promises rely in one way or another on the government’s ability and willingness to extract resources from the private sector. Each new resource-extracting promise affects the government’s ability to make good on the old ones. When payouts on government promises are positively correlated, adding an additional promise weakens the government’s ability to fulfill the other ones.

Generally, economists have not modeled bank and currency collapses in a single framework.<sup>8</sup> Among the few exceptions are Velasco (1987), Buch and Heinrich (1999) and Burnside, Eichenbaum and Rebelo (2000), but their models produce a tight linkage between bank and currency collapses. Velasco studies a banking collapse that leads inevitably to a currency collapse. A government guarantees bank deposits fully and responds to a bank collapse using its international reserves to redeem domestic deposits and assume the interest payments on banks’ foreign loans. The continued drain on reserves leads predictably to a currency collapse.

In Buch and Heinrich, a banking collapse also advances the time of currency collapse. A bad shock to bank asset returns lowers the net worth of banks and increases their cost of foreign borrowing. Since the government is already monetizing a fiscal deficit and losing international reserves, the decline in foreign borrowing speeds up the inevitable collapse of the fixed exchange rate.

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<sup>8</sup> For example, Chang and Velasco (1998a, 1998b, 1998c), Dooley (1998), and Allen and Gale (1999) study bank (or firm) and currency collapses but do not formally model the foreign-exchange market and currency collapse. In Chang -Velasco, either banks collapse or the fixed exchange rate does. In Dooley and Allen-Gale, bank and currency collapses occur together.

Burnside *et al* let a shift in market expectations trigger a joint collapse of the currency and the banks. They add a banking sector to a model of a self-fulfilling currency crisis along the lines of Obstfeld (1986). In their model, agents believe that if there is a successful attack on the currency, monetary policy will become more expansionary and validate their beliefs about currency depreciation. So speculators attack, and the monetary expansion does follow because the currency collapse increases the domestic-currency value of banks' foreign liabilities and requires a bank bailout financed partly by money creation.

In our work, we model both bank and currency collapses but these collapses need not occur together or sequentially. The range of possible outcomes corresponds more closely to historical experience, where there have been periods characterized only by banking crises, periods with only currency crises, and periods with both occurring together (twin crises). (Bordo and Eichengreen, 1999, Kaminsky and Reinhart, 1999). Our framework allows us to calculate the probability of each outcome and identify some factors that influence these probabilities.

The rest of the paper is organized as follows. Section 2 lays out the model. Section 3 analyzes the probabilities of various types of collapses using a simple graphical apparatus. Section 4 investigates collapse probabilities under an alternative public financing scheme for depositor bailouts. Section 5 draws some conclusions.

## 2. The Model

We study a small, open economy with a fixed exchange rate and a banking system that includes foreign-currency-denominated liabilities. The environment is stochastic and

agents have rational expectations. Bank and currency collapses result from current and accumulated bad shocks to fundamentals.<sup>9</sup> There is a single, economy-wide real shock that affects returns on bank assets, the demands for assets and government financing. Following a shock, the economy adjusts to a new equilibrium that is unique except in certain regulatory environments.

What are the conditions that trigger a bank or currency collapse? Our banks fail because they are broke, not because they face a liquidity problem. Banks fail when their liabilities exceed their assets. We call such an outcome a "bank collapse." The fixed exchange rate collapses when currency speculators rush to purchase all the government's international reserves committed to defense of the fixed rate. Speculators act the moment the shadow exchange rate exceeds the fixed rate, where the shadow rate is the flexible exchange rate that would prevail after the government's committed international reserves are exhausted (Flood and Garber, 1984). We call a successful speculative attack a "currency collapse."

In our small economy banks are risk neutral, but they enjoy possible bankruptcy protection should their investments turn bad. Because of the bankruptcy floor on banks' net worth, the banks must be regulated strictly and therefore behave mechanically.<sup>10</sup> To start a bank, an agent needs a license. The government distributes these licenses free of charge to favored insiders.<sup>11</sup> There is no requirement for bank owners/managers to capitalize the bank. Furthermore, should the banks go broke, the owners file for

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<sup>9</sup> Bad shocks that led to depositor bailouts in previous periods imply that the economy carries a larger stock of domestic credit or debt in the present and consequently has a more fragile currency peg.

<sup>10</sup> Because our focus is on collapse correlations, the behavior of actors is kept as simple as possible. We comment on this strategy below. The banks could be made more realistic at the cost of abandoning our simple graphical analysis.

bankruptcy, watch as their remaining assets are distributed to creditors and then exit as they arrived – with nothing.<sup>12</sup>

Banks play a valuable role in this economy because agents prefer using bank deposits and the attached government-supported clearing mechanism to make transactions. In the model we present, the government stands behind these deposits, pledging to bail out depositors fully should banks fail.<sup>13</sup> Since it is an important extension, we discuss in the appendix how our model can be adapted for partial depositor bailouts. Other roles for banks, such as pooling risks, are not explored here.

We assume also that our small economy is integrated in the international capital markets and that integration is invariant to crises.<sup>14</sup> Except for government regulations on the extent of banks' foreign-currency-denominated liabilities, there are no government controls on trade in financial assets.

The government's budget constraint is satisfied in one of two ways. In our first example, which is simple but not very realistic, depositor bailouts are financed by domestic credit creation. This case is straightforward because it builds directly on the KFG model. Our second case is more realistic -- depositor bailouts are financed by government debt and international reserves. In addition, the government manages the domestic-currency interest rate. We start with the first case because it is familiar and

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<sup>11</sup> We allow bank licenses to be priced and traded in a secondary market. Alternatively, we could have included bank-license sales as a government revenue source. This choice affects our results and we comment on it below.

<sup>12</sup> In the Indonesian crisis, "(t)he president's son, whose Bank Andromeda had been closed on November 1, (1997) was allowed to take over the small Alpha Bank, which was immediately granted a foreign exchange license by Bank Indonesia,... effectively reopening his former bank under a new name." (Lindgren *et al*, 1999, p. 59).

<sup>13</sup> The full government bailout of depositors is an important assumption that simplifies the presentation enormously. It also reflects the situation in the Asian crisis, where blanket guarantees to depositors were announced once the severity of the crisis was understood.

allows us to build a graphical apparatus appropriate for more complex environments such as the second case.

We now specify the model in greater detail, describing first an economy with a fixed exchange rate where the government monetizes the cost of any depositor bailouts.

### *The Banks*

We wish to determine how bad a shock must be to push banks to the break-even point, where bank assets just match bank liabilities. We begin by describing bank balance sheets.

Commercial banks accept domestic-currency deposits whose nominal value in levels is  $DD$ . The banks are required to hold a fraction of their demand deposits at the central bank as non-interest-bearing required reserves. Even if there is no reserve requirement, banks choose to hold this fraction of deposits for clearing purposes. Deposit liabilities net of these reserves is  $\gamma DD$ , where  $0 < \gamma < 1$ .

At the end of time  $t-1$  but before time  $t$  shocks are realized, banks take in deposits for time  $t$  and transform them net of required (riskless) reserves into risky productive investments, whose nominal value is  $A_{t-1}$ .<sup>15</sup> At time  $t$ , these investments yield an uncertain return whose value is:

$$R_t = 1 + (1 - \beta)\sigma r_t + \beta(s_t - \bar{s}) \quad (1)$$

$R_t$  is the gross return, which consists of three components. The first is unity as usual. The second is  $(1 - \beta)\sigma r_t$ , where  $(1 - \beta)$  is the portion of deposits invested in domestic

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<sup>14</sup> Our analysis would be quite different if the country's capital market integration were crisis dependent, e.g., importers could not obtain foreign exchange during a crisis period.

assets,  $r_t$  is the real shock that drives this model, and  $\sigma$  is a linearization constant that transforms the shock into loan performance. The third component of the return is  $\beta(s_t - \bar{s})$ , the percentage capital gain (loss) from foreign-currency denominated assets (liabilities). The level exchange rate is  $S_t$ . Its log is  $s_t$  and  $\bar{s}$  is the log of the fixed exchange rate.<sup>16</sup>

Think of a scenario where the bank borrows foreign-currency-denominated bonds at the fixed exchange rate. As an example, suppose they do not cover their exchange-rate risk and that the foreign interest rate is constant and set at zero. The stochastic return on this portfolio is then approximated by (1), with  $\beta < 0$ . Another example we shall study has the banks covering their expected foreign-currency exposure. Then the third term in (1) would be  $\beta(s_t - E_{t-1}s_t)$ , where  $E_{t-1}s_t$  is the time t-1 rational expectation of  $s_t$ . Alternatively, if banks cover fully their foreign-exchange exposure, such exposure would not be part of the bank return and  $\beta = 0$  in (1).

We assume that both  $\beta$  ( $\beta \leq 0$ ) and the required cover of foreign-currency exposure are regulated exogenously by the government.<sup>17</sup>

At time t-1, the balance sheet of commercial banks is

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<sup>15</sup> We call all of the safe assets “reserves”. The risky assets will be divided between domestic-currency-denominated investments and foreign-currency-denominated assets (liabilities).

<sup>16</sup> In the appendix we consider a case where an increase in the domestic interest rate improves the return on performing loans but reduces the share of performing loans in bank portfolios.

<sup>17</sup> We have not built risk aversion into our banks, but we do allow for bankruptcy. Absent strict regulation, the banks would take very risky positions to maximize the option value of their investments.

Assets	Liabilities
$A_{t-1}$	$\gamma DD_{t-1}$
	$NW_{t-1} = 0$

(2)

where the absence of capitalization indicates that the banks' net worth, NW, is zero. Productive investments,  $A_{t-1}$ , are held in the form of domestic-currency-denominated assets and foreign-currency-denominated assets (liabilities).

At time t, the balance sheet of banks is:

Assets	Liabilities
$R_t A_{t-1}$	$\gamma DD_{t-1}$
	$NW_t$

(3)

Banks just break even when their net assets ( $R_t A_{t-1}$ ) equal their deposit liabilities ( $\gamma DD_{t-1}$ ). Since  $A_{t-1} = \gamma DD_{t-1}$  from time t-1, we know that banks are at the break-even point at time t when:<sup>18</sup>

$$R_t = 1, \text{ or} \quad (4)$$

$$0 = (1 - \beta)\sigma r_t + \beta(s_t - \bar{s})$$

Figure 1 plots equation (4). Define  $f$  to be the shadow (log) exchange rate, the value a flexible exchange rate would take if the exchange-rate peg were attacked successfully. If  $\tilde{s} < \bar{s}$ , speculators take capital losses if they successfully attack the exchange rate, so there is no attack and  $s_t = \bar{s}$ . If instead  $f \geq \bar{s}$ , speculators can make capital gains, so they attack and  $s_t = f$ . Figure 1 plots the break-even points for banks, with  $r$  and  $s$  on the axes. Either the exchange rate is fixed at  $\bar{s}$  or it is variable for values above  $\bar{s}$ . When  $s_t = \bar{s}$  in (4), the value of the shock that equates bank assets and liabilities is  $r_t = 0$ . If the shadow rate should exceed the fixed exchange rate, the fixed exchange rate collapses, and the shadow rate becomes the operative exchange rate. Then  $s_t = f_t$  in (4) and the shock that drives banks to the break-even point is  $r_t = \frac{-\beta(f_t - \bar{s})}{(1 - \beta)\sigma}$ . The exchange rate that drives banks to the break-even point is  $f_t = \bar{s} - \frac{(1 - \beta)\sigma}{\beta} r_t$ .

If  $R$  falls below one, the banks collapse and the government fully compensates depositors for the deposits that banks are unable to redeem at par.<sup>19</sup> The depositor bailout is financed by unsterilized credit creation. If  $R \geq 1$ , banks are solvent and there is no credit creation. Thus:

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<sup>18</sup> Naturally,  $E_{t-1}NW_t > 0$  due to the bankruptcy provision. We assume that bank licenses trade in a secondary market.

<sup>19</sup>We wish to study the probability of crises when government policy is to fix the exchange rate as long as reserves are available and to bail out depositors fully using domestic credit creation or bond financing. To study the likelihood of crises when policies are set optimally, we would need to introduce a loss function where there is a trade off between the bank-deposit bailout and the minimum reserve level required to

$$\begin{aligned}
D_{t+1} - D_t &= (1 - R_t)\gamma DD && \text{if } R < 1 \\
D_{t+1} - D_t &= 0 && \text{if } R \geq 1
\end{aligned} \tag{5}$$

where  $D$  is the level of domestic credit, the amount of domestic assets held by the central bank. Defining  $d$  as the log of domestic credit, we rewrite (5) in logs after substituting (1) into (5), dividing both sides by  $D_t$  and normalizing the money multiplier so that  $\gamma DD/D = 1$ . Thus:

$$\begin{aligned}
d_{t+1} - d_t &= -(1 - \beta)\sigma r_t - \beta(s_t - \bar{s}) && \text{if } R < 1 \\
d_{t+1} - d_t &= 0 && \text{if } R \geq 1
\end{aligned} \tag{6}$$

If banks fail, the government bails out depositors and then distributes new bank licenses. Banks are back in business by the end of the period providing deposits to be used in the next period.<sup>20</sup>

To determine whether the fixed exchange rate collapses at time  $t$ , we need the value of the shadow exchange rate at time  $t$ , because the fixed rate collapses if  $\$t \geq \bar{s}$ . Recall that the shadow exchange rate is the rate that prevails if the fixed exchange rate is attacked, international reserves are driven to their lower bound, which we assume to be zero, and the exchange rate is allowed to float freely thereafter.

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maintain the peg. See Miller (2000) for an example of such a loss function. See the appendix for further discussion.

<sup>20</sup> Our model works equally well for any fixed period of bank closing.

The shadow exchange rate equilibrates the domestic money market *after* the collapse of the fixed exchange rate. We specify this post-collapse money market as:

$$m_t - \mathcal{f}_t = -\alpha(E_t \mathcal{f}_{t+1} - \mathcal{f}_t) + \delta r_t \quad (7)$$

In (7),  $m$  is the log of the nominal high-powered money supply. The nominal money supply is the sum of international reserves and domestic credit, but since the central bank has completely exhausted its international reserves defending the fixed exchange rate, the nominal money supply equals domestic credit after the exchange-rate collapse ( $m_t = d_t$ ). Nominal money balances are deflated by the domestic price level. Because we assume purchasing power parity, the price level is equal to the post-collapse shadow exchange rate,  $\mathcal{f}_t$ .

The right-hand side of (7) is the demand for real money balances. It depends negatively on the domestic interest rate, which in turn equals the expected rate of change of the exchange rate,  $E_t \mathcal{f}_{t+1} - \mathcal{f}_t$ , since uncovered interest parity is assumed to hold. In addition, the demand for money depends positively on the real shock,  $r_t$ .<sup>21</sup>

Since the money market in (7) is linear, we propose a linear solution for the shadow exchange rate of the form:

$$\mathcal{f}_t = \lambda_0 + \lambda_1 d_t + \lambda_2 r_t \quad (8)$$

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<sup>21</sup> If we wanted the real shock to affect firm balance sheets and lead to some of the income effects associated with crises suggested in Krugman (1999), we would model the  $\delta$  in money demand more carefully.

From (7), we know that the expected future exchange rate,  $E_t f_{t+1}$ , affects the shadow exchange rate at time  $t$ . Consequently, beliefs about possible future domestic credit growth resulting from future depositor bailouts are important in determining the shadow rate at time  $t$ . We present the simplifying case where banks are required to cover fully their foreign-currency liabilities (assets) after a currency collapse. Then the expected rate of domestic credit creation between period  $t+1$  and period  $t+2$  is:

$$E_t(d_{t+2} - d_{t+1}) = -\sigma \text{prob}(r_{t+1} < 0) (E_t r_{t+1} | r_{t+1} < 0) \quad (9)$$

In the far future ( $t+1$  and beyond) expected domestic credit growth equals the expected depositor bailout. The expected bailout depends on the probability that the disturbance will generate a bank collapse,  $\text{prob}(r_{t+1} < 0)$ , and the expected value of the real disturbance conditional on the disturbance generating a bank collapse ( $E_t r_{t+1} | r_{t+1} < 0$ ).<sup>22</sup> We assume the disturbance has a uniform distribution centered on  $\bar{r}$ , with upper bound  $\bar{r} + w$  and lower bound  $\bar{r} - w$ . Now (9) becomes:

$$E_t(d_{t+2} - d_{t+1}) = \frac{\sigma(\bar{r} - w)^2}{4w} \equiv \mu \quad (10)$$

Agents recognize that there may be bank failures in future periods  $t+1$ ,  $t+2$ , and so on, and therefore they expect future domestic credit expansion at rate  $\mu$ . As a result, they expect the future rate of currency depreciation to be  $\mu$  as well.

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<sup>22</sup> Banks collapse when  $R < 1$ . When banks cover fully their foreign-currency liabilities (assets) in all periods subsequent to the currency collapse, the condition that  $R < 1$  is identical to the condition that  $r < 0$ .

The expected future exchange rate can now be determined by examining the money market at  $t+1$ , one period after the collapse of the fixed exchange rate:

$$d_{t+1} - \mathcal{f}_{t+1} = -\alpha\mu + \delta r_{t+1} \quad (11)$$

Rearranging terms in (11), we find that the future exchange rate is  $\mathcal{f}_{t+1} = \alpha\mu + d_{t+1} - \delta r_{t+1}$  and its expected value at time  $t$  is  $E_t \mathcal{f}_{t+1} = \alpha\mu + d_{t+1} - \delta \bar{r}$ . Substituting our expression for the expected future exchange rate into the money market equation (7) yields:

$$d_t - \mathcal{f}_t = -\alpha[\alpha\mu + d_{t+1} - \delta \bar{r} - \mathcal{f}_t] + \delta r_t \quad (12)$$

$$\text{where } d_{t+1} = d_t - (1 - \beta)\sigma r_t - \beta(\mathcal{f}_t - \bar{s}) \mid R < 1$$

$$\text{and } d_{t+1} = d_t \mid R \geq 1$$

We now solve for two possible shadow exchange rates at time  $t$ , one conditional on bank collapse ( $R < 1$ ) and the other conditional on no bank collapse ( $R \geq 1$ ).

When the banks collapse at time  $t$ , the solution for the shadow rate is:

$$\mathcal{f}_t = \lambda_{10} + \lambda_{11}d_t + \lambda_{12}r_t$$

where

$$\lambda_{10} = \frac{(\alpha^2\mu - \alpha\delta\bar{r} + \alpha\beta\bar{s})}{(1 + \alpha + \alpha\beta)} \quad (13)$$

$$\lambda_{11} = \frac{(1 + \alpha)}{(1 + \alpha + \alpha\beta)}$$

$$\lambda_{12} = - \frac{[\alpha(1 - \beta)\sigma + \delta]}{(1 + \alpha + \alpha\beta)}$$

When banks are solvent at time  $t$ , the solution for the shadow rate is:

$$\tilde{s}_t = \lambda_{20} + \lambda_{21}d_t + \lambda_{22}r_t$$

where

$$\begin{aligned}\lambda_{20} &= \frac{\alpha^2\mu - \alpha\delta\bar{r}}{(1+\alpha)} \\ \lambda_{21} &= 1 \\ \lambda_{22} &= -\frac{\delta}{(1+\alpha)}\end{aligned}\tag{14}$$

### 3. Collapse Probabilities: A Graphical Representation

The two shadow exchange rate solutions, along with the break-even line for banks having net foreign liabilities, are graphed in a set of three figures, Figures 2-4. The figures can be used to illustrate the various possibilities for currency and bank collapse. First, notice there is a range of shock values for which there is no currency or bank collapse (labeled a in all figures), a range where there can be a currency collapse without a bank collapse (labeled b in Figure 2), a range where there can be a bank collapse without a currency collapse (labeled b' in Figure 3), and a range of shocks that bring about the simultaneous collapse of the currency and the banks (labeled c in all figures). Second, given our assumption of a uniformly-distributed real shock, we can use the figures to calculate the probability of the economy being in any particular range. Moreover, we can determine the factors that influence the probabilities of joint collapses, no collapses, and so on.

Before we analyze these probabilities, it is helpful to mention several things about the way the figures are constructed. First, the two shadow exchange rate lines in each figure are drawn for *a given value of domestic credit*. An increase in domestic credit shifts up the two lines, but by different amounts if bank returns are affected by exchange-rate changes (if  $\beta \neq 0$ ). Second, the slope of the shadow rate line conditional on bank collapse is steeper than the slope of the shadow rate line conditional on no bank collapse. Third, there is a discontinuity between the two shadow rate lines at the break-even point.

We can now calculate the probabilities of the various possible outcomes and observe the factors that influence these probabilities. We consider the case where banks have net foreign liabilities ( $\beta < 0$ ). In Figure 2, let  $r_a$  be the value of the shock where the shadow exchange rate conditional on no bank collapse just equals the exchange rate where banks break even. Let  $r_b$  be the value of the shock where the shadow exchange rate conditional on no bank collapse just equals the fixed exchange rate. Relying on our earlier assumption that the shock has a uniform distribution centered on  $\bar{r}$ , with upper bound  $\bar{r} + w$  and lower bound  $\bar{r} - w$ , the probability of no collapses is

$$\frac{\bar{r} + w - r_b}{2w} \quad \text{where} \quad r_b = \frac{(c_t^1 - \bar{s})(1 + \alpha)}{\delta} \quad \text{and} \quad c_t^1 = d_t + \frac{\alpha^2 \mu - \alpha \delta \bar{r}}{1 + \alpha}.$$

Not surprisingly, a higher level of domestic credit ( $d_t$ ) or a higher expected rate of domestic credit expansion in the future to finance depositor bailouts ( $\mu$ ) reduces the probability of no collapses. The more favorable on average is the shock ( $\bar{r}$ ), the greater the probability of no collapses.

In Figure 2, the probability of being in the range where there is a currency

$$\text{collapse but no bank collapse, is } \frac{r_b - r_a}{2w} \quad \text{where} \quad r_a = \frac{c_t^1 - \bar{s}}{\delta} - \frac{(1 - \beta)\sigma}{\beta} \quad \text{and} \quad r_b \quad \text{and} \quad c_t^1 \quad \text{were}$$

defined previously. For banks with net foreign liabilities, a greater sensitivity of bank returns to exchange-rate changes (a more negative  $\beta$ ) rotates down the positively-sloped segment of the break-even line, increases the value of  $r_a$ , and reduces the probability of a currency collapse without a bank collapse.

The probability of joint collapses is  $\frac{-\bar{r} + w + r_a}{2w}$ . The probability of joint collapses increases when the average shock is less favorable or has a higher variance, when the sensitivity of bank returns to exchange-rate changes is high, and when the future rate of domestic credit tied to depositor bailouts is high. The probability of joint collapses is also higher the greater is the stock of domestic credit in the economy.<sup>23</sup>

It may be helpful to the reader to compare Figure 2 with its counterpart derived from the Krugman, Flood and Garber model (KFG), a model that ignores the possibility of bank collapses. If we were to draw a KFG figure on axes of  $s$  and  $r$ , it would consist of the fixed exchange rate line at  $\bar{s}$  and a negatively-sloping line above regions a and b. The negatively-sloping line would be the KFG shadow rate line. It would cross through the horizontal fixed exchange-rate line and the bank break even line (in Figure 2), intersect the vertical axis and continue to the left boundary of  $r$ 's distribution. The KFG shadow-rate line would lie everywhere below the shadow-rate lines depicted in Figure 2 for two reasons: 1) In the region of no (current period) bank collapse, the KFG line would ignore the fiscal implications of future possible bank collapse. 2) In the (current period) bank collapse region, the KFG line obviously ignores the bank collapse evident to all in the model at hand.

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<sup>23</sup> We leave the calculations of the various probabilities of collapse in Figures 3 and 4 to the interested reader.

For these two reasons, a researcher studying possible currency collapse but failing to link the currency collapse to banking collapse will see (incorrectly) a stronger shadow value for the home currency than is appropriate. As usual, the strength of the shadow rate translates directly to the probability of currency collapse.

Our analysis relies on the assumption that there is a full depositor bailout and agents know that when they make deposits at the banks. In the appendix, we discuss what happens when there is uncertainty about the size of a bailout.

The framework above can be used to investigate the outcome when banks hedge their foreign-currency liabilities. Suppose, for example, that banks undertake neutral hedging. They obtain insurance so that in period  $t$  they will receive domestic currency whose spot foreign-currency equivalent covers their expected foreign-currency liabilities. On average, insurance allows the banks to avoid net gains or losses on their foreign-currency liabilities. Nevertheless, in periods where the spot rate exceeds what was expected, banks receive less domestic currency than they need to pay off their foreign-currency liabilities.

Since bank returns are reduced when the spot exchange rate exceeds its expected value, the break-even point for banks using risk-neutral hedging is:

$$R_t = 1 \tag{15}$$

where  $R_t = 1 + (1 - \beta)\sigma r_t + \beta(s_t - E_{t-1}s_t)$

In order to calculate the value of the shock that now drives banks to the break-even point, we must obtain an expression for the expected spot exchange rate in (15) and

then solve (15) for  $r_t$ . We obtain our expression for the expected spot rate by considering the case described by Figure 2. In that figure, the expected spot exchange rate at time  $t$  is a weighted average of the fixed exchange rate, the expected shadow exchange rate conditional on currency collapse but no bank collapse, and the expected shadow exchange rate conditional on currency collapse and bank collapse:

$$E_{t-1}s_t = \pi_1 \bar{s} + \pi_2 (E_{t-1}s_t | r_a < r_t < r_b) + (1 - \pi_1 - \pi_2) (E_{t-1}s_t | r_t < r_a) \quad (16)$$

with probability weights  $\pi_1 = \frac{(\bar{r} + w) - r_b}{2w}$ ,  $\pi_2 = \frac{r_b - r_a}{2w}$ ,  $\pi_3 = \frac{r_a - (\bar{r} - w)}{2w}$ .

Risk-neutral hedging alters the analysis in two fundamental ways. First, the adoption of risk-neutral hedging shifts the break-even line in Figure 2 to the left. When banks are covered against expected exchange-rate depreciation, it takes a more adverse shock to drive them to the break-even point. Second, the adoption of risk-neutral hedging raises the possibility of two feasible break-even lines. There can be two break-even lines because there are two possible values for the expected spot rate at time  $t$ .<sup>24</sup> If the economy settles on the higher expected spot rate and hedges on this basis, say by choosing a higher forward rate, then the economy will be hedged over a greater range of shock values. Consequently, the relevant break-even line is the one on the left in Figure 5 and a more adverse shock is required to drive banks to the break-even point. If the

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<sup>24</sup> Using (16) to calculate the expected spot rate, we observe that  $r_a$  is in the expression for the probability weight  $\pi_2$  and it is also in the expected value of the shadow rate conditional on currency collapse but no bank collapse. Additionally,  $r_a$  is in the probability weight  $\pi_3$  as well as in the expected value of the shadow rate conditional on both currency and bank collapses. Therefore the expected spot rate is a quadratic function of  $r_a$  and can take on two possible values.

economy settles on the lower expected spot rate and hedges on this basis, the relevant break-even line is the one on the right and the banks are more vulnerable to bad shocks.

Regardless of which expected spot rate the economy uses to form a risk-neutral hedge, hedging always makes banks less vulnerable to bad shocks than not covering at all. How does risk-neutral cover compare with full cover? When banks cover fully, exchange-rate changes do not affect bank returns and the break-even line is the vertical line at  $r=0$  in Figure 5. Risk-neutral cover provides greater bank protection from bad shocks than full cover only when the spot rate does not exceed its expected value for that period.

How do the various hedging strategies affect the probabilities of no collapse, a single collapse or joint collapses? As can be seen from Figure 5, the various hedging strategies do not alter the probability of no collapses. However, they can affect the probability of currency collapse and the probability of joint collapses. Compared with not covering foreign liabilities, risk-neutral hedging increases the range of shocks for which currency collapse can occur without bank collapse. It also reduces the range of bad shocks for which both the currency and banks collapse.<sup>25</sup>

So far we have identified factors that influence the joint probability distribution of currency and bank collapses on the assumption that a government finances depositor bailouts with domestic credit creation. This financing assumption is a familiar one from the KFG set up and it gives simple analytical solutions. However, it is unsatisfying since governments generally try to sterilize the liquidity support provided for bailouts and later

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<sup>25</sup> Our discussion ignores any cost of obtaining cover and the possible gain/loss that might arise from risk-neutral hedging when calculating the break-even point for banks. It also ignores the possibility that risk-neutral hedging may have affected bank demand for foreign-currency liabilities.

resort to bond financing and ultimately to tax increases. Our first example ignores also any attempt by the government to manage actively the domestic interest rate.

We next study a model with more realistic features. The good news is that the figures developed previously are invariant – in broad outline - to the adoption of a more realistic model. Thus the basic insights obtained from our earlier analysis carry over to a more realistic set up. Of course, the probabilities of various collapse outcomes are affected by model-specific factors.

#### 4. Financing Bailouts with Government Debt

We now study debt financing of depositor bailouts. In this situation, the government's budget constraint is expressed (in levels) as:

$$N_{t+1} - N_t = i(N_t - D_t) - S_t i^* V_t - S_t \tau_t + \Omega_t \quad (17)$$

$$\Omega_t = \begin{cases} 0 & \text{if no depositor bailout} \\ (1 - R_t) \gamma DD_t & \text{if full depositor bailout} \end{cases}$$

The government's net deficit determines the evolution of the total stock of outstanding government nominal debt,  $N$ . The government must make interest payments equal to  $i(N-D)$  on the portion of government debt not held by the central bank as domestic credit. The government receives interest payments on international reserve holdings equal to  $S_i^*V$ , where  $i^*$  is the interest rate earned on foreign-currency reserve holdings,  $V$ , and the price level is equal to the spot exchange rate  $S$  assuming purchasing power parity. The government also receives tax payments net of expenditure,  $S\tau$ , where  $\tau$  is the real primary surplus. We assume that nominal tax revenue as a share of nominal government

debt depends on the real shock. Finally, the government may be required to spend  $(1-R)\gamma DD$  to bail out depositors should the banks collapse.

The interest parity condition reflects the notion that domestic and foreign bonds are imperfect substitutes:

$$i = i^* + \frac{E_t S_{t+1} - S_t}{S_t} + \theta \left[ \frac{B_t}{S_t} \right], \quad (18)$$

where  $B_t = N_t - D_t$  is the quantity of domestic bonds held privately and  $\theta \left[ \frac{B_t}{S_t} \right]$  is the risk premium. The domestic interest rate must compensate international investors not only for expected depreciation of the home currency but also for risk that increases with the quantity of domestic bonds in investors' portfolios. We assume that  $\theta$  is a positive parameter.<sup>26</sup> The domestic interest rate is managed actively by the government. We consider it an exogenous variable.

We log-linearize (17) and (18) in the appendix and solve them for the (log) shadow exchange rate conditional on no bank collapse and the (log) shadow rate conditional on bank collapse. These shadow exchange rate solutions take the form:

$$f_t = \gamma_0 + \gamma_1 n_t + \gamma_2 r_t \quad (19)$$

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<sup>26</sup> Our justification for a wedge in UIP is the assumption that domestic and foreign-currency bonds are imperfect substitutes in agents' portfolios. At a deeper level, imperfect substitution may reflect a utility-based bias toward own-currency assets that could be derived from those assets having a *liquidity* advantage over foreign-currency assets (see Lahiri and Végh, 1999). The wedge could equally well result from increasing marginal domestic-currency borrowing costs (see Drazen, 1999). The function we use here is derived from risk aversion in Jeanne and Rose (1999). Flood and Marion (2000) derive a wedge proportional to the ratio of domestic bonds to foreign bonds in investors' portfolio

where  $n$  is the log of nominal government debt and the  $\gamma_i$  coefficients differ across the two solutions.

Our specification for the banks' break-even point is the same as it was in our first model specification.

The two shadow exchange rates, as well as banks' break-even point are shown graphically using the same set of figures as before. The two shadow rate lines are drawn for a given stock of outstanding government debt, and an increase in that debt will shift up both lines, though not by the same amounts.<sup>27</sup> Our earlier Figures 2-4 can again be used to illustrate the various possible outcomes for the case where banks do not cover their foreign liabilities. Figure 5 can again be used to illustrate a possible outcome when banks engage in risk-neutral hedging. Of course, since our model specification is now different, different factors will affect the probabilities of collapse.

For example, if the economy is characterized by Figure 2, the probability of no collapses is once again  $\frac{(\bar{r} + w) - r_b}{2w}$ , where  $r_b$  is the value of the shock where the shadow

rate conditional on no bank collapse equals the fixed exchange rate. We know

$$r_b = \frac{\bar{s} - \gamma_0 - \gamma_1 \Omega_t}{\gamma_2},$$

where the  $\gamma_i$  solutions are given in the appendix. Now the

probability of no collapse depends on a much richer set of factors, such as tax policy, interest-rate policy, the risk premium, the stock of nominal government debt, the share of

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<sup>27</sup> If the government had auctioned bank licenses instead of giving them away, the added government revenues would mean less bond financing. As a result, the shadow exchange rate lines would shift down, increasing the chance of avoiding collapses.

government debt held by the central bank, the value of the fixed exchange rate, and the size of future bailouts, and the mean value of the shock and its variance.

For example, larger tax revenues are associated with a higher probability of no collapses. Larger tax revenues reduce the amount of needed bond financing, thereby reducing the value of the shadow exchange rate. A higher foreign interest rate reduces the probability of no collapse since it makes foreign assets more attractive to hold and thereby increases the value of the shadow exchange rate. An increase in the domestic interest rate has an ambiguous effect on the shadow exchange rate. It makes domestic assets more attractive to hold but it also requires the government to issue more bonds to cover its increased interest payments on the debt. Moreover, if interest rates are allowed to influence bank fragility, a change in domestic interest rates can shift the break-even line.

## 5. Conclusion

We have presented a simple graphical framework that allows us to link multiple policy promises to the underlying fiscal resources that ensure performance on those promises. We considered two well-known promises: (1) to fix the price of the domestic currency in terms of a foreign currency and (2) to fix the price of domestic bank deposits in terms of domestic currency. The examples we studied differed primarily in terms of the fiscal resources available to government. In the first example, the only government revenue source was seigniorage. In the second example, we introduced taxes and interest-paying debt.

Our examples were chosen to illustrate two points. First, banking and currency crisis are related, but they are not the same thing. Sometimes they occur together, but not always. Viewing crises in isolation or as joint events biases estimates of the likelihood of crises. Second, the proliferation of government promises reduces the likelihood of keeping any individual promise when the resources devoted to keeping the promises are fixed. The second point is easy to forget. When KFG studied currency crises, their results were based on a fixed commitment to a single promise. Adding a second promise – this time to bail out the banks – will raise the probability of currency crisis, thereby pushing up domestic interest rates as well.

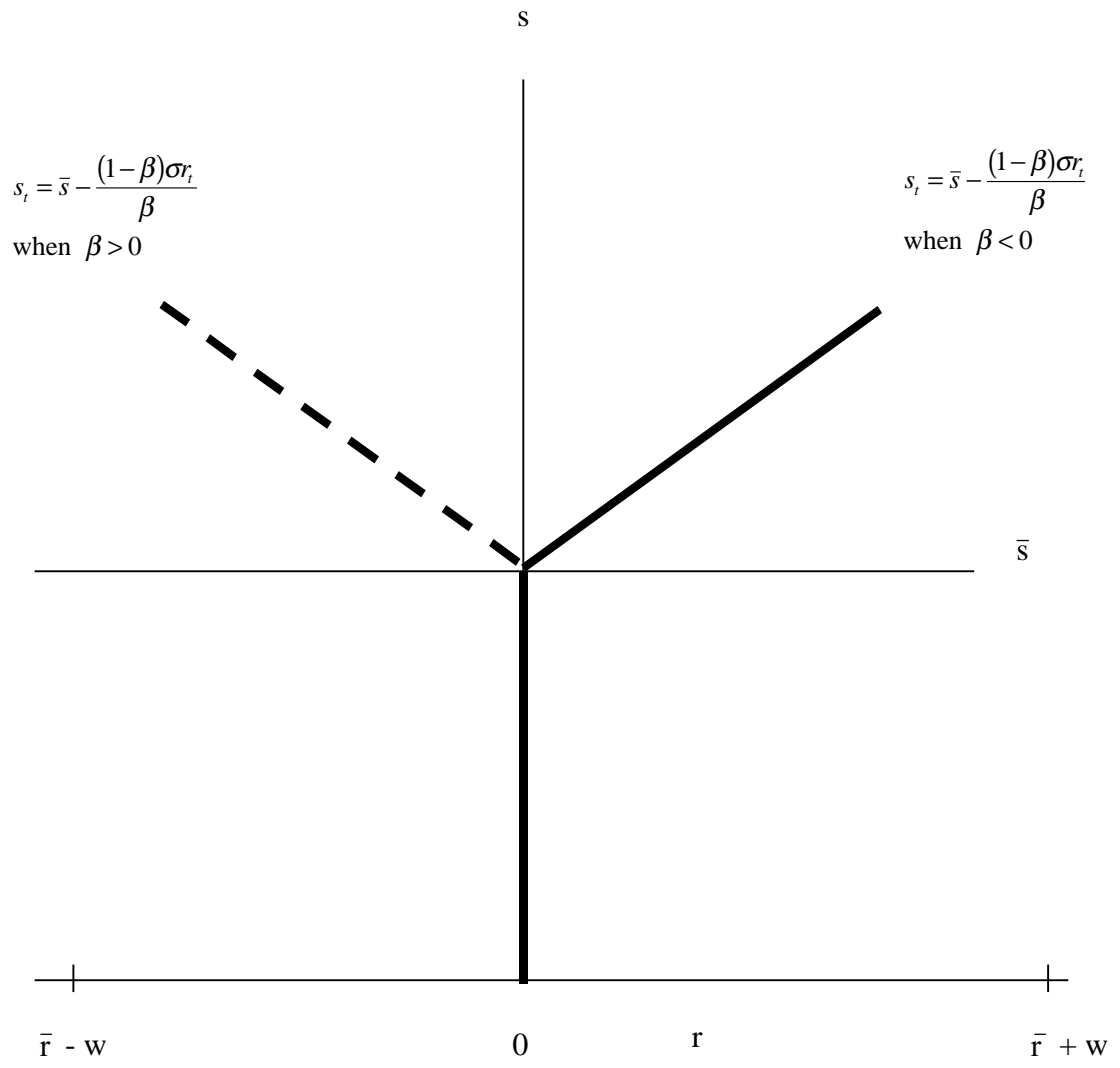


FIGURE 1: The Break Even Point for Banks

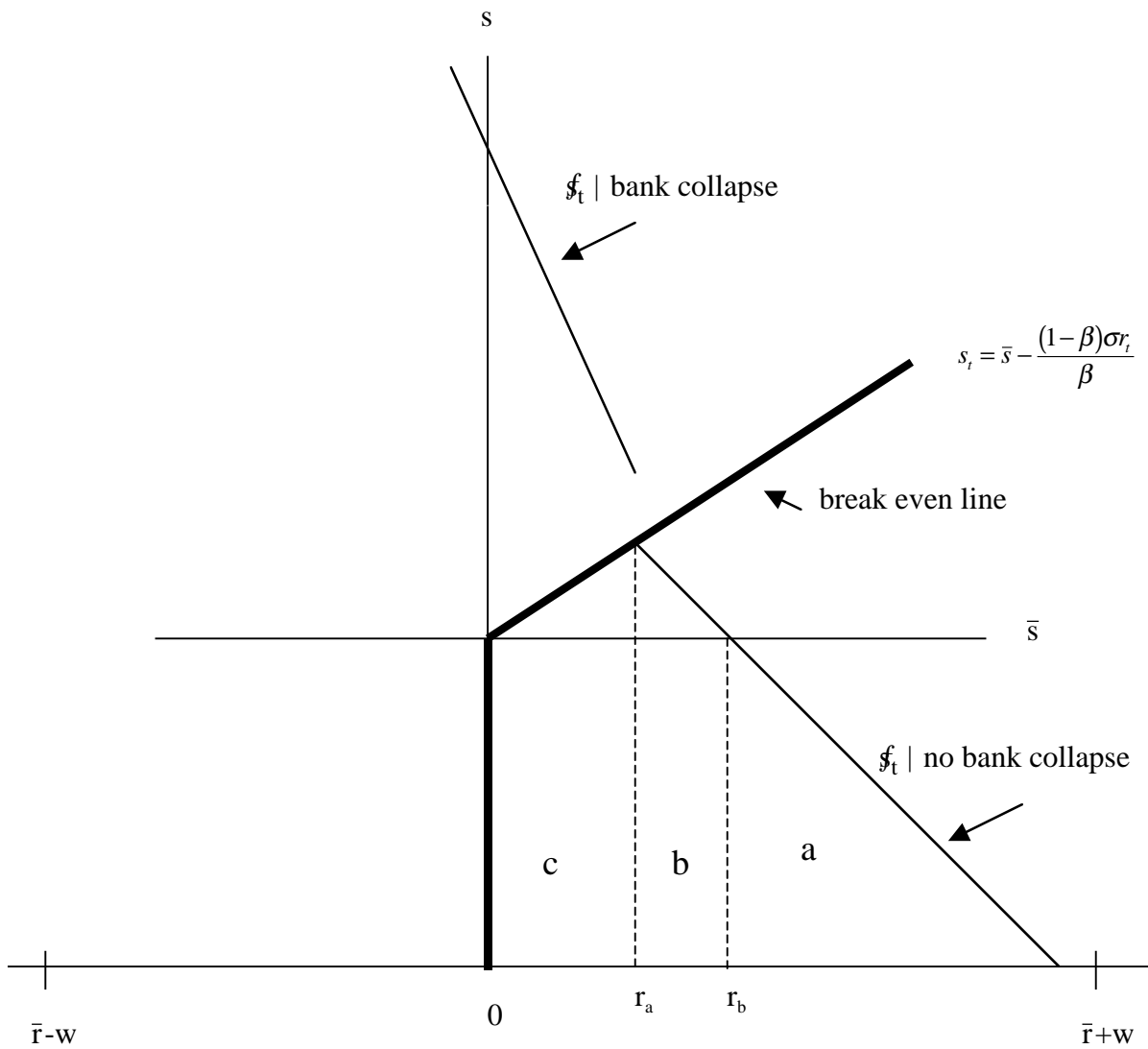


FIGURE 2: Collapses, Including Currency Collapse Without Bank Collapse

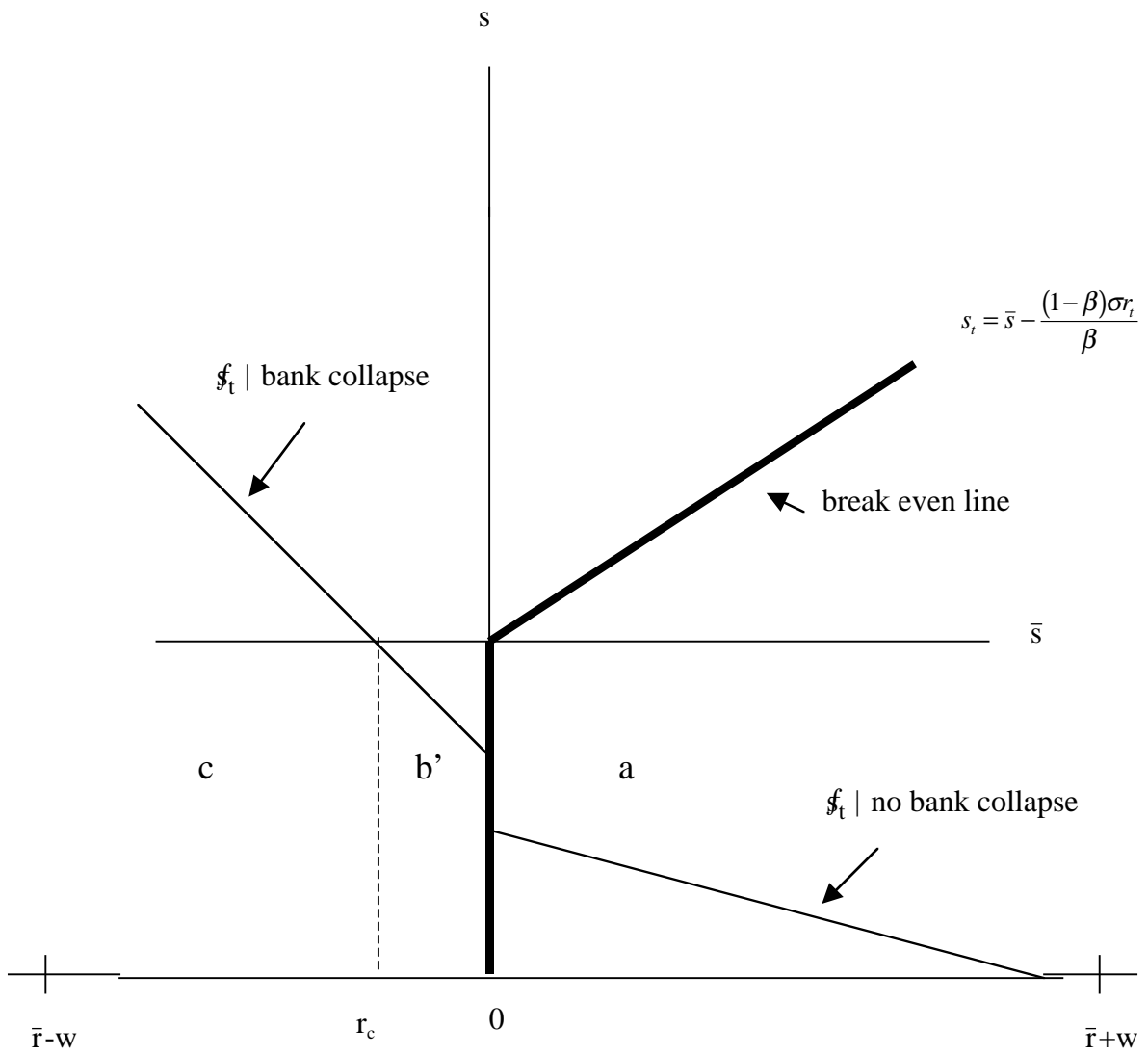


FIGURE 3: Collapses, Including Bank Collapse Without Currency Collapse

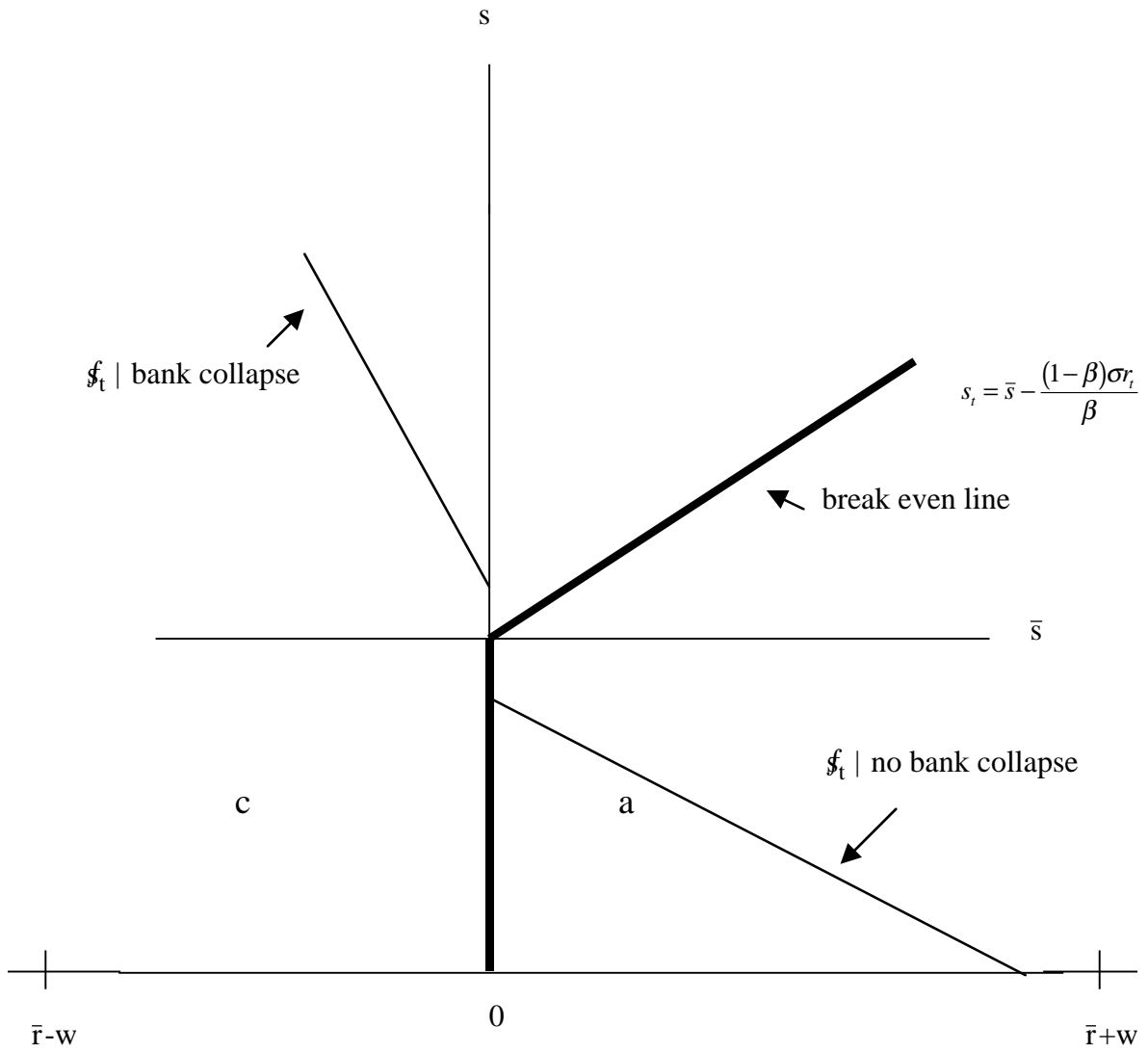


FIGURE 4: Joint Collapses or No Collapses

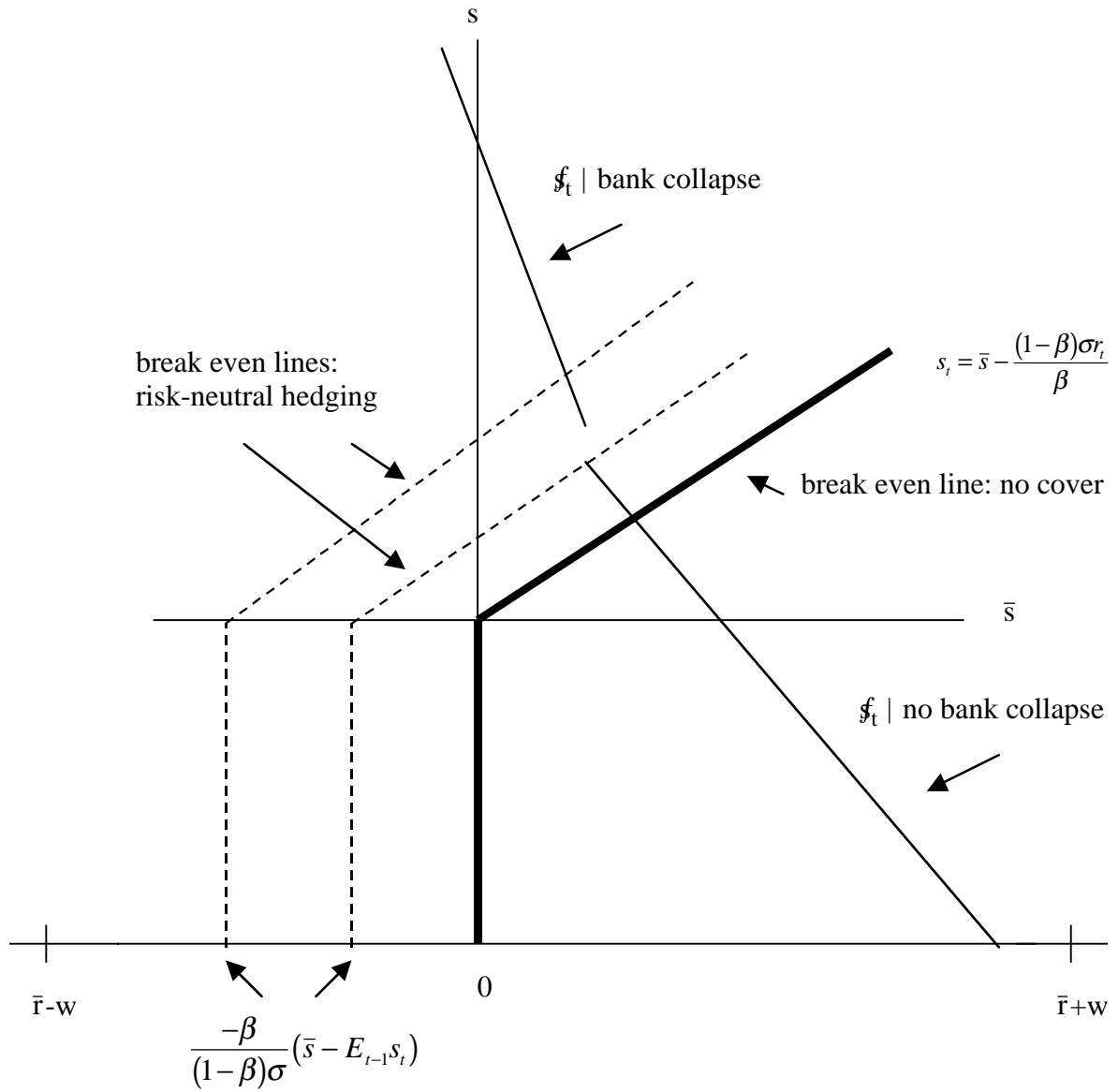


FIGURE 5: Collapses with Risk-Neutral Hedging

## Appendix

### A.I. Model Solution When Bailouts Are Bond Financed

In the second version of the model, depositor bailouts are financed by government debt. The government also manages the interest rate. In this appendix, we specify the equations of the model, linearize them, and derive the solutions for the shadow exchange rate conditional on no bank collapse and the shadow rate conditional on bank collapse.

The government budget constraint, equation (17) in the text, is:

$$N_{t+1} - N_t = i(N_t - D_t) - S_t i^* V_t - S_t \tau_t + \Omega \quad (\text{A1})$$

$$\Omega = \begin{cases} 0 & \text{if no depositor bailout} \\ (1-R_t)\gamma DD_t & \text{if full depositor bailout} \end{cases}$$

The variables in (A1) are defined in the text. Dividing both sides of (A1) by  $N_t$  gives:

$$\frac{N_{t+1} - N_t}{N_t} = i\left(1 - \frac{D_t}{N_t}\right) - \frac{S_t i^* V_t}{N_t} - \frac{S_t \tau_t}{N_t} + \frac{\Omega}{N} \quad (\text{A2})$$

We now linearize (A2). Let lower-case letters (except for interest rates) represent logs, so  $n_t = \ln N_t$ . Then the left-hand side of (A2) is

$$\frac{N_{t+1} - N_t}{N_t} = n_{t+1} - n_t \quad (\text{A3})$$

Let  $X_t \approx a + bx$ , where  $x = \ln X$ . Then

$$\frac{D_t}{N_t} = f_0 + f_1(d_t - n_t) \quad (\text{A4})$$

where  $f_0 = \left(\frac{\bar{D}}{N}\right)\left[1 - \ln\left(\frac{\bar{D}}{N}\right)\right]$ ,  $f_1 = \frac{\bar{D}}{N}$ , and a bar over a variable indicates its average value.

After the fixed exchange-rate collapses, the government does not receive interest on central bank foreign reserve holdings since reserves have been depleted defending the fixed exchange rate. The second term on the right-hand side of (A2) is therefore zero.

We assume that the ratio of nominal taxes to nominal debt is a linear function of the real shock,  $r$ . Tax revenues increase (decrease) when the real shock is more (less) favorable than its average value. Thus the third term on the right-hand side of (A2) is:

$$\frac{S_t \tau_t}{N_t} = T_0 + T_1(r_t - \bar{r}) \quad (\text{A5})$$

where  $T_0$  is the average value of nominal taxes relative to nominal debt.

Recognizing that  $XY = \bar{X}Y + \bar{Y}X - \bar{X}\bar{Y}$ , we can linearize the bailout term in (A2) as:

$$\frac{(1 - R_t)\gamma DD_t}{N_t} = \frac{\overline{\gamma DD}}{N} (1 - R_t) + (\overline{1 - R})\gamma \frac{DD_t}{N_t} - \frac{\overline{\gamma DD}}{N} (\overline{1 - R}). \quad (\text{A6})$$

Further, let  $\ln\left(\frac{DD_t}{N_t}\right) = s_t + dd_t - n_t$ , where  $DD$  is the (level) value of nominal demand deposits and  $dd$  is the log of real demand deposits. Thus the linearization of the bailout term in (A6) is:

$$\frac{(1 - R_t)\gamma DD_t}{N_t} = \beta_0 + \beta_1[s_t + dd_t - n_t] + \beta_2(1 - R_t) \quad (\text{A7})$$

where  $\beta_0 = \frac{-\overline{\gamma DD}}{N} (\overline{1 - R})$ ,  $\beta_1 = (\overline{1 - R})\gamma$ ,  $\beta_2 = \frac{\overline{\gamma DD}}{N}$ , and bank returns

are  $R_t = 1 + (1 - \beta)\sigma r_t + \beta(s_t - \bar{s})$  when banks do not cover their foreign-currency exposure.

Substituting (A3)-(A5) and (A7) into (A2) and recalling that international reserves are depleted once the fixed exchange rate collapses, the linearized version of the government budget constraint in (A2) becomes:

$$n_{t+1} - n_t = i[1 - f_0 - f_1(d_t - n_t)] - T_0 - T_1(r_t - \bar{r}) \quad (\text{A8})$$

$$+ \begin{cases} 0 & \text{if no bailout} \\ \beta_0 + \beta_1[s_t + dd_t - n_t] + \beta_2(1 - R_t) & \text{if full bailout} \end{cases}$$

The portfolio equation, equation (18) in the text, is:

$$i = i^* + \frac{E_t S_{t+1} - S_t}{S_t} + \theta \left[ \frac{N_t - D_t}{S_t} \right] \quad (\text{A9})$$

To linearize the third term on the right-hand side of (A9), we first convert  $[N_t - D_t]$  to  $(1 + \delta)n_t - \delta d_t$ , with  $0 < \delta < 1$ . Since  $X \approx a + bx$ , the linearization of the third term is:

$$\frac{N_t - D_t}{S_t} = f_2 + f_3[(1 + \delta)n_t - \delta d_t - s_t] \quad (\text{A10})$$

In addition, the linearization of the second term on the right-hand side of (A9) is:

$$\frac{E_t S_{t+1} - S_t}{S_t} = E_t s_{t+1} - s_t \quad (\text{A11})$$

Substituting (A10) and (A11) into (A9) yields:

$$i = i^* + E_t s_{t+1} - s_t + \theta[f_2 + f_3\{(1 + \delta)n_t - \delta d_t - s_t\}] \quad (\text{A12})$$

Further, after the depletion of foreign reserves and an exchange-rate collapse, domestic credit equals the sum of demand deposits and currency, which we specify as:

$$d_{t+1} = s_{t+1} + \alpha_0 - \alpha_1 i + \alpha_2 r_{t+1} \quad (\text{A13})$$

We conjecture that the shadow exchange rate at time t+1 takes the form:

$$f_{t+1} = \lambda_0 + \lambda_1 n_{t+1} + \lambda_2 r_{t+1} + \lambda_3 u_{t+1} \quad (\text{A14})$$

where  $u_{t+1}$  is the part of the depositor bailout made at time t+1 that is unexpected at time

t. We also conjecture that the shadow exchange rate at time t takes the form:

$$f_t = \gamma_0 + \gamma_1 n_t + \gamma_2 r_t \quad (\text{A15})$$

Using (A13)-(A15) and solving (A8) and (A12), we find that the shadow exchange rate conditional on no bank collapse is:

$$f_t | \text{no bank collapse} = \gamma_0 + \gamma_1 n_t + \gamma_2 r_t \quad (\text{A16})$$

where

$$\gamma_0 = \frac{\Lambda}{\Gamma}$$

$$\text{with } \Lambda = i^* - i + \lambda_0 + \lambda_2 \bar{r} + \theta f_2 + i(1 - f_0) - T_0 + T_1 \bar{r} - [\theta f_3 \delta + if_1][\alpha_0 - \alpha_1 i]$$

$$\Gamma = 1 + if_1 + \theta f_3(1 + \delta)$$

$$\gamma_1 = 1$$

$$\gamma_2 = \frac{-[T_1 + (\theta f_3 \delta + if_1)\alpha_2]}{\Gamma}$$

The shadow exchange rate conditional on bank collapse is:

$$f_t | \text{bank collapse} = \gamma_0^* + \gamma_1^* n_t + \gamma_2^* r_t \quad (\text{A17})$$

where

$$\gamma_0^* = \frac{\Lambda + \beta_0 + \beta_1(\alpha_0 - \alpha_1 i) + \beta_2 \beta \bar{r}}{\Gamma - \beta_1 + \beta_2 \beta}$$

$$\gamma_1^* = \frac{\Gamma - \beta_1}{\Gamma - \beta_1 + \beta_2 \beta}$$

$$\gamma_2^* = \frac{-[T_1 + (\theta f_3 \delta + if_1)\alpha_2 + \beta_2(1 - \beta)\sigma]}{\Gamma - \beta_1 + \beta_2 \beta}$$

## A.II. Bank Returns

In this section of the appendix, we consider a more complicated return on bank assets that yields two possible break-even points for banks, even when exchange rates are fixed. Suppose banks hold their domestic assets in mortgages and the banks are regulated in terms of what they can charge on mortgage interest and on how much foreign debt they can hold. Then the bank's assets ( $A$ ) evolve according to:

$$A_t = A_{t-1}[(1 - \beta)(1 + \xi i^* (\sigma r_t / r_u)) + \beta(1 + i^*)S_t / S_{t-1}] \quad (\text{A18})$$

where  $(1 - \beta)$  is the share of bank deposits held in domestic assets ( $\beta \leq 0$ ),  $r_t$  is a real shock,  $r_u$  is the upper bound of this uniformly-distributed shock,  $r_t / r_u$  measures the favorability of the current shock,  $\sigma$  is a constant that transforms the shock into loan performance,  $i^*$  is the foreign interest rate and  $\xi$  is controlled by bank regulators. The proportion of performing loans is  $\sigma r_t / r_u$ . The banks are mechanical, but that is the price they pay for being allowed to provide deposits and to go bankrupt when things go bad.

Let us look first at the mortgage interest rate in (A18),  $\xi i^* (\sigma r_t / r_u)$ . One possibility is to assume that banks can charge a rate proportional to the rate they could get on foreign assets – not accounting for possible currency depreciation - but grossed up on average to account for possible non-performing loans. If, for example, bank regulators set the mortgage interest rate such that mortgages are expected to pay off the same as foreign-currency assets – not counting currency depreciation – then:

$$i^* = E_t \xi i^* (\sigma r_t / r_u) = \xi i^* \bar{\sigma} / r_u, \quad (\text{A19})$$

Therefore  $\xi = r_u / \bar{r} \sigma$ . That is, of course, just one possibility for mortgage-rate regulation. Regulators could also allow banks to account for possible currency depreciation, in which case there will be an expected depreciation term in (A19) that will be state-dependent, complicating the derivations but not changing them in a fundamental way.

The second term in (A18) can be linearized as  $(1+i^*)S_t / S_{t-1} \cong (1+i^*)(1+s_t - s_{t-1})$ . Our more complete expression for the return on assets is therefore:

$$R_t = 1 + \beta i^* + (1 - \beta) z r_t + \beta(1+i^*)(s_t - \bar{s}), \quad (\text{A20})$$

where  $z = i^* \sigma / \bar{r}$ .

Notice that in this model, being able to borrow in domestic currency and lend in foreign currency is a good deal. Risk-neutral banks need to be regulated or they will put all their deposits into foreign currency and wait for a collapse. They will, of course fight to make  $\beta$  big and also fight to raise the mortgage rate.

The real shock that takes banks to the break-even point (where  $R_t = 1$ ) is now  $r_t = \frac{-\beta i^* - \beta(1+i^*)(s_t - \bar{s})}{(1-\beta)(\frac{i^* \sigma}{\bar{r}})}$ . It depends on the bank's net foreign asset or liability position,

the foreign interest rate, the average value of the shock, the parameter that translates the shock into performance, and whether the fixed exchange rate is operating. Note that even when  $f_t < \bar{s}$  so that  $s_t = \bar{s}$ , that is, even when the fixed exchange rate is in operation, there

are two different bank break-even lines. It takes a smaller bad shock to collapse banks with net foreign liabilities than banks with net foreign assets, even when the fixed exchange rate is maintained.

Things are more interesting if we allow loan performance to depend on the interest rate. (See Stiglitz and Weiss (1981)). Suppose the government regulates the interest rate earned on bank assets. Then when banks are allowed to charge a higher interest rate, there is a greater chance that a given loan will be unable to perform. In our model, the mortgage payoff would become:

$$(1 + \xi i \sigma(r_t / r_u)) \text{ where } \sigma = \sigma(\xi i) \text{ and } \sigma' < 0.$$

Note that the bank or bank regulators can still select  $\xi$ . In this setup, the bank break-even point may or may not be a monotonic function of  $i$ . It depends on what bank regulators do. There are different strategies for setting  $\xi$ . For example, regulators could set  $\xi$  to maximize bank survival or to maximize regulator survival. Different regulatory choices will give different break-even lines.

### A.III. Partial Bailouts

In this section of the appendix we consider some implications of a stochastic payout on deposits that can range from zero (no bailout of depositors) to one (complete bailout). Suppose agents derive utility from consumption and from holding currency and demand deposits. They

$$\max V = \sum [u(c) + v(z) + w(qd)] \tag{A21}$$

subject to:

$$P_t c_t = P_t y + (1 + i_{t-1})b_{t-1} + z_{t-1} + q_t d_{t-1} - b_t - z_t - d_t,$$

where  $c$  = consumption

$z$  = currency

$d$  = deposits at banks

$q$  = pay-out rate on deposits (normally  $q = 1$ )

$b$  = nominal bonds

$i$  = the interest rate

The optimization yields some familiar first-order conditions and a new one. The first-order condition (FOC) for holding currency is:

$$(-u'_t + v'_t) / P_t + \rho u'_{t+1} / P_{t+1} = 0 \quad (\text{A22})$$

The FOC for holding deposits is:

$$-u'_t / P_t + \rho u'_{t+1} q_{t+1} / P_{t+1} + \rho w'_{t+1} q_{t+1} / P_{t+1} = 0 \quad (\text{A23})$$

so the demand for deposits depends on the future pay-out rate. The FOC for holding bonds is:

$$-u'_t / P_t + \rho u'_{t+1} (1 + i_t) / P_{t+1} = 0 \quad (\text{A24})$$

Since  $c = y$ , let  $u^\xi$  be constant. Marginal utilities  $v^\xi$  and  $w^\xi$  depend on currency and deposits. We obtain the following currency and deposit demand functions:

$$Z_t / P_t = f(y, i_t) \quad (\text{A25})$$

$$D_t / P_t = g(y, i_t, q_{t+1}) \quad (\text{A26})$$

The demand for money is now

$$M / P = f(y, i) + (1 - \gamma)g(y, i, q_{t+1}) \quad (\text{A27})$$

In the text, we have set  $q = 1$  (and ignored the income effect on money demand) and that simplifies the money demand function. If the deposit redemption rate is stochastic and ranges between zero and one, the shadow exchange-rate specification becomes:  $f_t = \lambda_{10} + \lambda_{11}d_t + \lambda_{12}r_t + \lambda_{13}q_t$ . The redemption rate now affects the shadow exchange rate, but the direction of the effect depends on parameter values. A smaller expected redemption rate in the event of bank collapse reduces the demand for bank deposits and thereby reduces money demand. A smaller expected redemption rate also implies less domestic credit creation in the event of possible future bank collapses and hence a smaller expected rate of future currency depreciation. That factor tends to increase money demand. If the former effect dominates,  $\lambda_{13} < 0$ . Then, in contrast to the case in the text of a complete bailout, a partial bailout will generate shadow exchange-rate lines everywhere above those in the figures. Reducing the size of the expected bailout introduces greater fragility. It reduces the probability of no collapses and increases the probability of joint collapses.

Ultimately, it would be helpful to have a theory of what determines the deposit redemption rate,  $q$ . This theory can be anything from having some dedicated reserves for bank failure separate from the reserves dedicated to the fixed exchange rate, to having the government optimize period by period some social loss function that sets the limits on both the defense of the currency and the defense of the banks.

As a step towards such a theory, we could introduce a stochastic  $q$  and assume there is some maximum total bailout for the period – reserve capital loss plus bank depositor bailout. We could then derive the resource allocation scheme between defending the banks and defending the currency. As a start, the resource allocation scheme could be specified as exogenously random. It could even be based on the one real shock described in the text.

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