

Insuring Against Self-Fulfilling Financial Crises

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Abstract

This paper proposes an insurance scheme to protect a currency from self-fulfilling financial crises. Treating such crises as catastrophes, the recently developed catastrophe insurance bond (CAT bond) can be adapted and applied. The idea is for the insured currency area to issue bonds with an interest payment higher than market alternatives and relieve the area's debt burden (principal and interest) in case of a catastrophic crisis. There are two purposes behind such a design: first, if a crisis occurs, the area being hit can use the forfeited principal as funds to recover; second and more importantly, the bondholders will have an incentive to defend against the speculative attack causing the crisis because they will themselves want to avoid the forfeiture of their debt principal. We study two typical models with self-fulfilling expectations by Obstfeld (1996) and Krugman (1999) and analyze the resulting equilibrium with and without the CAT bond. It is shown that under some conditions, the insurance scheme can indeed help to reduce the threat of a self-fulfilling financial crisis.

Key words: Asian financial crisis; CAT bond; exchange rate

JEL classification: F31; G22

1. Introduction

Since the Asian financial crises of 1997–1998, dozens of papers have discussed issues related to such crises. Three major lines of discussion have arisen: (1) What are the causes of these financial crises? (2) What can the government do when similar incidences happen or are about to happen? (3) What can be or should be done afterwards, either by the government in question or by international

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organizations such as the IMF. Below we shall briefly review some of the findings in the literature, and then discuss the rationale of this paper.

1.1 Causes of the Asian financial crises

According to Radelet and Sachs (1998), the Asian financial crises can be attributed to three major factors: the international factor, the domestic factor, and intrinsic market failure. After a careful review of the evidence, they find that these crises should not be attributed to deteriorating domestic or international fundamentals of the kind which contributed to crises in other countries in the past. Leaving aside some minor domestic mismanagement in these Asian countries, detrimental though this was, the Asian financial crises are believed to be the result of an unpredictable self-fulfilling financial panic, a phenomenon typical of market failure. Krugman (1999) reaches the same conclusion in his study of the problem, and similar observations are made by researchers studying other market crises (e.g., Eichengreen et al., 1995; Kaminsky and Reinhart, 1996; Obstfeld, 1996).

A key feature of a self-fulfilling crisis, as is clear from the analysis of Obstfeld (1996) and Radelet and Sachs (1998), is the collective action of economic agents. The collective action may be prompted either by random shocks such as sunspots or the direction given by an obvious market leader, say the Quantum Fund led by Soros. In either case, if the intrinsic self-fulfillingness is believed to be the major reason for the financial crisis, then relatively little can be proposed in the way of future preventive policies. As a self-fulfilling crisis may happen even if the country's financial management is solid, tough measures are sometimes proposed, such as regulating short-term capital flows. Understandably, however, such regulatory proposals have aroused different assessments among economists (see Krugman, 1999). Apart from tough regulatory measures, is there anything else that a country can do to stop the collective action leading to crises? We shall argue in the following sections that there is. The rationale of our design will become clear as we proceed to the next subsection.

1.2 The catastrophe bond

Recent literature on insurance has introduced a series of insurance innovations to deal with the rare, massive shocks that cause huge losses, namely catastrophes. The need for such innovations is obvious following the Northridge earthquake and Hurricane Andrew. After these two events, some local and regional insurance companies covering the impacted areas became insolvent. Moreover, there was a severe tightening in the world catastrophe reinsurance markets, as reinsurers reduced the availability of catastrophe coverage (Pollner, 2001). The major reason for the failure of the traditional insurance contract is that such catastrophes usually cause massive damages that need coverage at the same time. For various reasons such as moral hazard and transaction costs, as argued in Doherty (1997), insurance companies cannot reinsure themselves against these unpredictable huge risks that hit a particular place at an unforeseen time, and the catastrophe risks thus become what

traditional textbook writers call “not ideally insurable.” Even where they are insured, the capacity of the insurance industry may limit the availability of adequate protection. Cummins et al. (2002) find that the capacity of the U.S. property-liability insurance industry is sufficient to finance catastrophic losses in the \$100 billion range. However, such an event would cause numerous insolvencies and severely destabilize insurance markets.

As Jaffee and Russell (1997) point out, there is nothing in the nature of a catastrophic risk that prevents insuring against it in the private market. As it is local and infrequent, it is certainly diversifiable. Moreover, the capital markets have far larger capacity—a catastrophic loss of \$100 billion magnitude represents less than one standard deviation of the daily value traded in the U.S. capital markets (Froot, 2001). With this belief in mind, (re)insurers, investment banks, and brokerage firms have come up with three major innovations to deal with catastrophic risk: nonindemnity hedges, contingent refinancing, and debt forgiveness. An introduction to the first two innovations can be found in Doherty (1997); here we pay more attention to the third one, which is more directly related to our discussion below.

1.3 The intuition of this paper

The idea of the third innovation is to compensate the suffering party not by making a payment but by forgiving a debt. For instance, the state of Florida, which has been sporadically hit by hurricanes, can issue bonds to outsiders, called catastrophe bonds or CAT bonds. When a catastrophe (defined by specified events) hits an area, the principal or interest or both of the bonds will be forgiven by the bondholders, becoming in effect available to the issuing authority as funds to deal with the catastrophe, e.g., to cover rebuilding expenses. As a form of a risk premium, the CAT bond pays a higher coupon rate to bondholders if the specified events do not happen. The principal proceeds of the bond are usually held in trust. The idea of a CAT bond has now been implemented and is growing in popularity, although different names have been given to it. Much evidence can be found in Jaffee and Russell (1997), Froot (2001), and Pollner (2001) and thus is not repeated here.

Suppose that there is no serious financial mismanagement within a country, and suppose that the domestic and international conditions are basically sound. If a random sunspot occurs which triggers a self-fulfilling financial panic and causes a serious drop in investment and output, this sunspot shock in the financial order is analogous a catastrophe in the natural order. Treating an event like this as a catastrophe, it is natural to ask: Can a government design a bond similar to the CAT bond to insure against “sunspot risk?” If so, it would have an advantage lacking in the natural disaster case. The CAT bond places the onus of risk on the bondholders, who forfeit their principal in the case of a catastrophic event. It follows that CAT bondholders have an incentive to defend against any speculative attack that has the aim of profiting from the envisioned catastrophe. As such, a CAT bond that is designed with respect to financial crises not only has an insurance role but also contains a strategic role: taking the case of an attack on a currency, it transforms what would have been speculation-followers into domestic-currency defenders. As

we shall see in Sections 2 and 3, a well-designed CAT bond can prevent an otherwise unavoidable financial crisis. Finally, in a case where the financial crisis really happens, the country in question still has the trusted bond principal as a post-crisis rebuilding fund.

To present the argument that the idea of a CAT bond can be applied, we adopt the typical models of financial crises in the literature and introduce the CAT bond idea into these models. In particular, we consider two frameworks: the Obstfeld (1996) setup and the Krugman (1999) setup. The first-generation financial crisis models (e.g., Flood and Garber, 1984) are not considered because therein the crisis eventually occurs as the government tries to defend a target that is inconsistent with the fundamentals. This kind of fundamental inconsistency cannot be removed by insurance. Evidently, as already suggested by the first-generation models, the fixed exchange rate is not appropriate for economies with poor fundamentals.

The rest of this paper is arranged as follows. In Sections 2 and 3, respectively, we consider the models of Obstfeld (1996) and Krugman (1999) and show how the CAT bond can be designed to prevent otherwise unavoidable crises. To show that the CAT bond so designed can be used to counteract well-known speculative attackers such as Soros, the bond is sometimes called the “Soros bond” simply in the interest of the pleasure of reading. The last section discusses one possible application example and extensions.

2. The CAT Bond in Obstfeld’s Model of a Currency Crisis

In the classic paper, Obstfeld (1996) considers a game played by three agents. Here we make only minor changes; all other specifications are exactly the same.

2.1 The scenario without CAT bonds

The government holds an amount of reserves R and tries to defend the fixed exchange rate. There are two traders, one is Q (signifying the Quantum Fund operator), who is a professional speculator, and the other is F (signifying a follower of Q), who is less experienced. These two agents hold some domestic currency and can either hold it or sell it to the government. Each trader is assumed to incur some transaction costs when selling the currency. This is the only difference between our specification and that in Obstfeld. It is assumed that the transaction cost, which can embody the implicit risk premium, is 1 unit for trader F and $1-\varepsilon$ units for the more experienced trader Q , where ε is positive. If the implicit risk premium is included in ε then, since Quantum Fund players are usually less risk-averse than followers, the transaction costs of a speculative attack for the latter would be larger. In this case, the bond is more attractive to the followers, and inequality (1) as found in Section 2.3 will have to be rewritten, but all of our results remain valid.

Each trader is assumed to have 6 units of domestic currency resources, and the government has R units of reserves, somewhere between 6 and 12. This is because if R is smaller than 6 or greater than 12, either one trader can defeat the government’s fixed exchange rate alone or both traders combined cannot defeat the

government, and neither of these cases is of interest. If both traders sell and succeed in defeating the government, then the domestic currency is assumed to devalue 50%. The government's exhausted reserve is assumed to be evenly shared by the two traders. When this happens, each trader gains $(50\%) \times R/2 = R/4$ units. If any single trader moves alone, the exchange rate will not change, and the selling agent will incur a loss of 1 unit unilaterally. The payoff matrix is as shown in Figure 1. Since $6 < R < 12$ by assumption, sell/sell is the Pareto-dominant Nash equilibrium (over hold/hold) in Figure 1. It is likely that both traders will try to sell, the government will fail to defend and will lose all R units of reserves, and the fixed exchange rate will be defeated. Here the depreciation expectation of the domestic currency is indeed self-fulfilling: as long as both traders expect that there will be depreciation, they will both sell, and the currency will depreciate.

Figure 1. Payoff Matrix without CAT Bonds ($6 < R < 12$)

		Trader Q	
		Hold	Sell
Trader F	Hold	0, 0	0, $-1 + \varepsilon$
	Sell	-1, 0	$R/4 - 1$, $R/4 - 1 + \varepsilon$

2.2 The scenario with CAT bonds

We now introduce the CAT bond insurance scheme and see how this alters the situation. To simplify the introduction of the idea of a Soros bond in financial crises, we only consider the one-period scenario and ignore the possible complications associated with multi-period dynamics; it is easy to adapt the results for dynamic scenarios. In fact, most CAT bonds that currently exist in the market are one-year bonds. We also assume that there is no secondary market for such bonds. If there is a particular secondary market for these bonds, then an additional restriction other than (3), as found later in Section 2.3, may be needed to sustain our arguments. The intersection of these restrictions will constitute the parametric range for the success of the CAT insurance design, and none of our conclusions will be affected qualitatively. Suppose that the government decides to issue an amount B of bonds, of which the holder will be paid $1 + \bar{r}$ for each dollar of bond investment at the end of the period if the currency does not devalue. Suppose that the opportunity rate of return is r^* . Then, $\bar{r} - r^*$ is the risk premium of the Soros bond. If the domestic currency does devalue, say by 50%, defined as the critical event, then neither the interest nor the principal will be repaid. The trust holding this bond principal will use the money to fund recovery according to prespecified rules.

A currency authority intending to sell the Soros bond has two policy variables to decide. The first is the discount price at which to sell the amount B of bonds; the second is the interest premium \bar{r} . To simplify the analysis, we ignore the discount price and consider only the interest premium. For the Soros bond to be effective in defending against speculative attacks, it has to fulfill the following conditions: (a) at least one trader is attracted by the high interest payment and is willing to buy it; (b)

at least one buyer of the bond does not want to sell the domestic currency to initiate or join a speculative attack, so that the domestic currency will not devalue; and (c) the benefit to the government of defending the currency successfully minus the interest premium paid out (and other floating costs for issuing Soros bonds) must be positive.

We now write down the payoff matrix when the Soros bond is issued. The payoff matrix will be different when only one trader buys the bond and when both traders buy the bond. In equilibrium the former case is impossible. This is so because if one trader decides to buy it, the other trader acting alone can never succeed in defeating the government, and hence the other trader will decide to buy the bond (and enjoy the higher interest) too. Thus, we only have to draw the case when both traders decide to buy the bond. To facilitate the calculation, it is further assumed that these two traders each get half of the B bonds. The corresponding payoff matrix is drawn in Figure 2. Our purpose is to find the conditions under which hold/hold in Figure 2 will become a dominant-strategy equilibrium. If that occurs, the domestic currency will not devalue, and hence condition (b) in the previous paragraph is satisfied. Readers should note an implicit assumption that the bonds are sold to the two traders in foreign currency so that after the traders buy the bond, their ability to buy foreign currency will not change. The revenue is held by a trust so that no one can use it. This assumption is made purely to simplify the presentation. If the Soros bond is sold to the two traders in domestic currency, then the traders' ability to attack the domestic currency is further weakened, and our result is strengthened.

Figure 2. Payoff Matrix with CAT Bonds ($6 < R < 12$)

		Trader Q	
		Hold	Sell
Trader F	Hold	$\bar{r}B/2, \bar{r}B/2$	$\bar{r}B/2, \bar{r}B/2 - 1 + \varepsilon$
	Sell	$\bar{r}B/2 - 1, \bar{r}B/2$	$R/4 - 1 - B/2, R/4 - 1 + \varepsilon - B/2$

2.3 Sustainable conditions for CAT bonds

In order for us to write down the payoff numbers in Figure 2, several implicit assumptions have been made. First, \bar{r} must be high enough so that the player Q is willing to buy the bond in the first place. Specifically, comparing the Pareto-dominant payoff in the southeast corner of Figure 1 and that in the northwest corner of Figure 2, we need:

$$\frac{\bar{r}B}{2} > \frac{R}{4} - 1 + \varepsilon. \quad (1)$$

Note that when (1) holds,

$$\frac{\bar{r}B}{2} > \frac{R}{4} - 1,$$

meaning that trader F is also willing to buy the bond. Thus, condition (a) above is satisfied if inequality (1) is fulfilled. Furthermore, (1) also implies that:

$$\frac{\bar{r}B}{2} > \frac{R}{4} - 1 - \frac{B}{2} \quad \text{and} \quad \frac{\bar{r}B}{2} > \frac{R}{4} - 1 + \varepsilon - \frac{B}{2}.$$

Thus, hold/hold is indeed a dominant strategy in Figure 2. This validates condition (b).

Finally, we have to verify that the government's return is better under the CAT bond scenario than otherwise. Originally, the government loses the amount of $R/2$. In the CAT bond scenario, assuming floating costs are negligible, the government now loses the premium $\bar{r}B/2 + \bar{r}B/2 = \bar{r}B$. Therefore, as long as:

$$\bar{r}B < \frac{R}{2}, \quad (2)$$

the Soros bond scenario will make the government better off. Combining (1) and (2), we have:

$$\frac{R}{4} - 1 + \varepsilon < \frac{\bar{r}B}{2} < \frac{R}{4}. \quad (3)$$

Recall that r^* is the opportunity rate of return available in the world market with $r^* < \bar{r}$. If the reserve amount R is rather low, evidently inequality (3) and $r^* < \bar{r}$ cannot be satisfied at the same time. When R is large enough, we can almost always find \bar{r} and B to fulfill (3).

To be more realistic, suppose that there exists uncertainty with respect to government reserves due to random shocks. Let the probability of having low (high) reserves be q ($1-q$), the value of q being common knowledge to players of the game. If it turns out that the government has high reserves, then Q and F combined cannot defeat the government, and hence it will be in neither's interest ever to sell the currency. If the government has low reserves, then the game is the same as described above. In this case, the condition for the Soros bond to work changes to:

$$\frac{qR}{4} - 1 + \varepsilon < \frac{\bar{r}B}{2} < \frac{qR}{4}. \quad (3')$$

Evidently the first inequality in condition (3') is less restrictive than that in (3), but the second inequality is more stringent. In any event, related conditions may be changed, but the insight is the same.

It should be emphasized that the above models characterize rather simple scenarios, and we cannot draw too much inference out of the parameter range in (3) or (3'). We have worked out more sophisticated scenarios, e.g., when the number of traders is more than 2 and each has a different spectrum of transaction costs and

when the Soros bond can be bought by a third party (other than the two traders). Our result is robust, and nothing changes qualitatively. The intuition here is that the result associated with the speculative attack is a negative-sum one; while each trader gains an amount corresponding to loss incurred by the government, the traders' gains are reduced by the transaction costs. Thus, there is room for improvement. The idea of CAT bond insurance is to shift the sudden huge impact at the moment of the crisis to ordinary time in a smooth way. By doing so, the otherwise large transaction costs when the crisis occurs are saved. Of course, it is already clear from (3) that if R is very small, meaning that the government is rather weak in defending its currency, then the risk of currency crisis is simply too large to be insured by the CAT bond. In addition, if the floating costs for the government to issue Soros bonds are too large, it will have no incentive to adopt this approach to protect the currency.

2.4 The moral hazard problem

As discussed in Doherty (2000), moral hazard is an unavoidable byproduct in all insurance policies. In our context, the government that issues the CAT bond secures an insurance-type protection by transferring risks of currency devaluation to bondholders. This might reduce the government's incentive to take action to decrease the likelihood or severity of a possible currency crisis. If the insured government fails to sustain its efforts to maintain the originally sound fundamentals as at the time before the Soros bond was issued, the resultant losses will be borne by bondholders.

To formally examine this issue, assume that the reserve held by the insured government is a non-decreasing function of the government's management effort, α , normalized so that the unit cost of effort is 1. The government's payoff is:

$$R(\alpha) \cdot (1 + r^*) - \alpha. \quad (4)$$

The first-order condition implies that $R' \cdot (1 + r^*) - 1 = 0$. The optimal level of management efforts will be determined by the trade-off between marginal benefits and costs. Now after issuing the amount B of Soros bonds, the government's payoff becomes:

$$(R(\alpha) + B) \cdot (1 + r^*) - \alpha - I_{\{R(\alpha) > S\}} B(1 + \bar{r}), \quad (5)$$

where $I_{\{R(\alpha) > S\}}$ is an indicator function equal to 1 if $R(\alpha) > S$ and 0 otherwise. The value of S is a predetermined level of reserves below which the bond is in default. While in default, neither the interest nor the principal will be repaid to bondholders. Otherwise bondholders should receive $1 + r^*$ for each dollar of bonds held. Now, with the protection of the CAT bond, the cost of mismanagement (low α) will be partly shared by bondholders, as the resulting lower reserves will reduce the likelihood of the bonds being repaid. The addition of the third term reflects the negative effect of the insured government's moral hazard, and hence the level of the government management effort will be below the optimal level.

We can introduce a contract incentive mechanism to raise the level of management effort on the part of government. Suppose that the bondholders are entitled to receive $h \cdot P(R, S)$ when the bond is in default, where $P(R, S) = \max\{S - R, 0\}$ is a put-option type of payoff function and h is a penalty ratio. With this design, although lower management efforts (α) will reduce the likelihood of the insured government's repaying the bonds, they will also increase the likelihood and quantity of the penalty payment. Properly designed, this mechanism could mitigate the moral hazard problem and induce management efforts toward the optimal level, as suggested by the first-order condition of Equation (4).

The above analysis was based on a specific game with only two players and without an explicit macroeconomic context. To further generalize our point, we now turn to the "third-generation" models, or those designed to capture the Asian financial crises in particular. Readers may have other settings in mind, but here we follow the framework of Krugman (1999) and take into account the idea of the Soros bond accordingly.

3. The CAT Bond in Krugman's Model of a Currency Crisis

Admitting the explanatory power of factors such as crony capitalism and over-borrowing in the Asian financial crises, Krugman (1999) argued in his recent working paper that large foreign debt itself may also generate a self-fulfilling financial panic. The specific model he proposed is as follows.

3.1 Fundamental setup

Consider an open economy that produces a single good through a Cobb-Douglas production function:

$$y + G(K, L) = K^a L^{1-a},$$

where K is capital and L is labor. Krugman (1999) assumed that the capital lasts for only one period, so that any default problem associated with long-term investment is assumed away. Workers get share $1 - a$ of the produced income and use all of it in consumption. Entrepreneurs, who own all the capital, get the other a share of income and save and invest all of their income. It is further assumed that there is a unitary elasticity between the domestically produced good and the good that is produced abroad. Specifically, for both consumption and investment spending, a share μ is spent on imported goods and the other $1 - \mu$ is spent on domestic goods. Finally, the rest of the world is assumed to have a fixed amount of export demand from the domestic country, which is denoted X in terms of foreign goods. Let the exchange rate be p ; then the exports in terms of domestic goods is pX .

Given the above setup, the market clearance condition for the domestic good can be written as:

$$\begin{aligned} y &= (1 - \mu)I + (1 - \mu)C + pX \\ &= (1 - \mu)I + (1 - a)(1 - \mu)y + pX, \end{aligned}$$

which implies the following determination equation for the exchange rate:

$$p = \frac{y[1 - (1 - a)(1 - \mu)] - (1 - \mu)I}{X}. \quad (6)$$

Krugman (1999) then assumed that, apart from financing from their own savings, entrepreneurs can borrow at most a proportion θ of their initial wealth for investment. Thus,

$$I \leq (1 + \theta)W, \quad (7)$$

where W is the initial wealth. Of course, entrepreneurs do not have to invest up to the borrowing upper bound $I_f \equiv (1 + \theta)W$; the internal rate of return of investment has to be considered.

Given the aggregate production function G , the marginal return on investment in terms of domestic goods is:

$$(1 + r) = G_k(I_{-1}p^{-\mu}, L),$$

where the subscript -1 indicates that the variable in question is lagged one period and $p^{-\mu}$ is the price index for investment relative to domestic output since the share μ of investment falls on foreign goods. Suppose the return on the foreign bond is r^* , which is a constant. Domestic investment can continue as long as the following inequality is satisfied:

$$(1 + r) \cdot \frac{p}{p_{+1}} \geq 1 + r^*, \quad (8)$$

where the subscript $+1$ indicates that the variable in question is evaluated one period ahead. Furthermore, investment also has to fulfill the non-negativity constraint:

$$I \geq 0. \quad (9)$$

Let D and F be the net debts of domestic entrepreneurs indexed to domestic and foreign goods, respectively. The entrepreneurs' net wealth is their share of income deducted by debts. Thus, we have:

$$W = ay - D - pF. \quad (10)$$

As p is a function of I by (6), an increase in investment will appreciate the domestic currency (reducing p), which by (10) increases the domestic wealth. Specifically, for any given income y , we have

$$\frac{dW}{dI} = \frac{(1-\mu)F}{X}. \tag{11}$$

When the investment is high so that the credit constraint in (7) is binding, investment will then be equal to I_f . Thus, through the real wealth effect in (11), we find that the investment upper bound will be affected by I through the following equation:

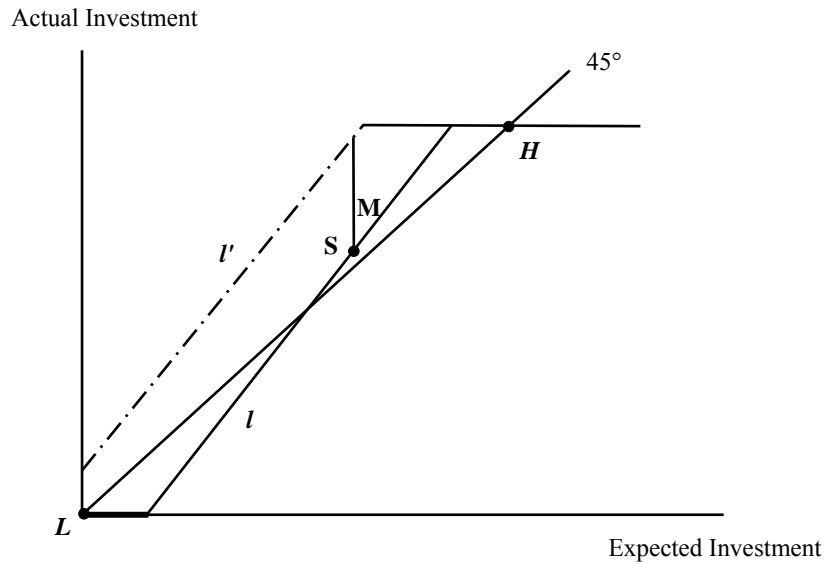
$$\frac{dI_f}{dI} = \frac{(1+\theta)(1-\mu)F}{X}. \tag{12}$$

Equation (12) tells us that the investment has a self-propelling or self-fulfilling effect. As long as this self-propelling effect is strong enough, characterized by the condition that the slope of I_f with respect to I is larger than one:

$$\frac{(1+\theta)(1-\mu)F}{X} > 1,$$

then it is easy to see that there may be multiple rational expectation equilibria in the model. We reproduce Krugman's (1999) Figure in Figure 3 and discuss the cases one by one.

Figure 3. Krugman's Model with and without CAT Bonds



When I is expected to be in the low range, firms are bankrupt and do not invest at all, so that the non-negativity constraint (9) is binding. In this case, the equilibrium will be at point L in Figure 3. When the expected investment is in the medium range, the expectation-realization interaction characterized in (12) applies, and firms will invest up to the borrowing upper bound (7). For this medium-investment range, the dynamics are characterized by the upward-sloping line l with slope $(1+\theta)(1-\mu)F/X$, which is assumed to be larger than 1 in Figure 3. When the investment increases along with line l , the return to investment gradually falls. When investment reaches a point high enough for (8) to be satisfied, the investment will be constrained by the real interest rate parity condition in (8). In that situation an increase in investment expectation can no longer increase real investment, and the equilibrium will be at point H .

In Figure 3, there are three equilibria, the middle of which is not stable. The important point here is that both H and L are self-fulfilling, so that with the help of the wealth effect associated with the exchange rate, even a panic without fundamental support can shift the equilibrium from H to L . Krugman (1999) suggested that this self-fulfilling panic may in fact be the true cause of the Asian financial crises.

3.2 Introducing CAT bonds

If Krugman's model is correct, what can a government do to avoid such a self-fulfilling panic? One possibility is to make the slope of the line l less than 1, which can be obtained by reducing the leverage (θ), increasing the marginal propensity to import (μ), and reducing the foreign currency debt (F). Other than such changes in fundamentals, some of which are obviously costly, is there any other way we can think of to insure against such a self-fulfilling panic? To put it differently, if the government has just found that its θ , μ , and F are in reasonable ranges and it is reluctant to change due to structural reasons, then can the government exert some insurance effort to reduce the probability of such a self-fulfilling panic?

Let us consider the following strategy: the government issues an amount B of CAT bonds to foreign banks, paying interest $\bar{r}B$ to the bondholder if the investment does not shrink much. However, if the investment shrinks by, say, one third, it is defined as a catastrophe, so that the interest and principal of the CAT bond will no longer be paid. It is expected (to be verified later) that if the investment does fall by this magnitude, the foreign banks will step in and invest an amount M . By doing so, the foreign banks will liquidate some of their original investment, which is assumed to cost them cM . Now, will this Soros bond scenario work?

Let us consider the safest case. If the foreign bank does step in and invest M , then the true investment is determined by the following function, as we have explained above:

$$I(I^e) = [ay - D - p(I^e)F](1+\theta) + M, \quad (13)$$

where I^e denotes the expectation of investment and $p(I^e)$ is the price determined from (6) when the investment on the right-hand side is replaced by I^e . The line characterized by (13) is denoted l' in Figure 3, which is a vertically upward shift of line l . In Figure 3, we denote S the (arbitrary) critical point set and announced by the foreign bank: if the actual investment is lower than S , the bank will step in and invest M . If $I(0) > 0$, then the new l' line has a positive vertical intercept when $I^e = 0$ (see Figure 3). When this is the case, point L is no longer securely in equilibrium. That is why we argue that this is the safest case to consider.

Using (6), we see that $p = y[1 - (1-a)(1-\mu)]/X$ when $I = 0$. Substituting this result into (13), we see that the $I(0) > 0$ condition requires that:

$$I(0) = \left[ay - D - F \cdot \frac{y[1 - (1-a)(1-\mu)]}{X} \right] \cdot (1 + \theta) + M > 0. \quad (14)$$

This condition is likely to be satisfied, for instance, when M is large or D is small.

For the foreign banks to buy this Soros bond in the first place, it must be the case that the interest premium they earn $(\bar{r} - r^*) \cdot B$ is larger than the possible costs that the banks will incur when they have to buy an amount M of investment, cM . (Note that this M investment is only needed to bring the ordinary investors back to the H equilibrium. When this expectation-leading purpose is fulfilled, the foreign banks can take back the money.) However, if the market has rational expectations, and if the following inequality holds:

$$cM < (1 + \bar{r})B, \quad (15)$$

meaning that the foreign banks' cost of defending the country's investment is smaller than the cost of forfeiting the Soros bond, then the foreign banks will indeed step in and defend when a catastrophe hits. Thus, if (14) and (15) hold, all the speculators are persuaded that the market is now credibly "protected" and hence are not willing to attack. The net return to the foreign banks then is in fact $(\bar{r} - r^*) \cdot B$, which is positive. In summary, when (14) and (15) hold, the foreign banks will be willing to buy the Soros bond and defend the domestic investment in case of an attack.

The final question is: will the government be willing to pay the cost of $(\bar{r} - r^*) \cdot B$ to insure against the possible sunspot drop from H to L ? The answer is yes if the distance between H and L is large enough and the probability of a speculative attack is high enough. Certainly, if θ and F are too large, indicating that the country in question is in really bad shape, then the size of M that is needed to satisfy inequality (14) will be very large, which in turn will make the value of B or \bar{r} needed to satisfy (15) rather large as well. In that case, the Soros bond insurance is not workable, or at least the insurance in question cannot be complete.

If M is not large enough so that $I(0)$ is still negative, then the L equilibrium cannot be ruled out for sure. Suppose the probability of a successful attack can be assessed. Foreign banks then may still have the incentive to buy the Soros bond and

defend the domestic country in case of an attack. The calculation involves an arbitrary but straightforward digression and is therefore omitted.

The above model is again rather simple, and we should not draw too much inference about the parameter ranges derived in (14) and (15). However, we should emphasize the intuition here, which is similar to that in Section 2. When there is the possibility that the economy will be shifted from the high equilibrium at H to the low equilibrium at L (in Figure 3) by a speculative attack initiated by purely random events such as sunspots, it is not likely that such events cannot be insured against. A speculative attack on a country is just like a natural catastrophe. As long as the range between H and L is large enough, we can always issue a Soros bond to share the risk with outsiders.

3.3 Moral hazard revisited

Once again, caution must be exercised vis-à-vis the moral hazard problem on the side of the insured party: Would the country that has issued a Soros bond be reckless in its leverage or banking management because it is insured? Would the country intentionally deflate its currency just for the purpose of receiving the trust fund? This moral hazard problem would not be serious for purely random catastrophes; but it may be serious for our case where the insured country has some room for maneuver.

As mentioned in the previous section, the problem of moral hazard is not specific to the case of catastrophe insurance; it is a problem of nearly all insurance contracts. In Section 2 we introduced a mechanism involving option-type claims by bondholders that can mitigate the problem. As an alternative, a simpler monitoring-based mechanism can be incorporated into the bond structure. In the case of the model presented in this section, for instance, it can be specified in the contract that θ (the financial leverage), F/X (the foreign debt ratio), or other monetary policy measures should not exceed a certain upper bound, otherwise the contract will be void and the trust will return the proceeds to the bondholders. In our opinion, monitoring the financial behavior of a country is relatively easier than monitoring individuals. In the practice of the natural hazard CAT bond issuance, as a matter of fact, companies or government authorities that have issued such bonds have usually worked closely with bond rating organizations to maintain the fair risk-adjusted rating of the bonds.

4. Conclusions

This paper extends two currency crises models by adding an insurance element. It contributes to the literature by demonstrating how the idea of a Soros bond can be embodied in models of self-fulfilling financial crises and how the bond can serve insurance and strategic purposes and obviate undesirable outcomes. While we believe the mixture of insights from currency crises models and insurance innovations is fruitful, we have emphasized that the scenarios presented here are straightforward extensions of theoretical models and that any application should

come with much detailed specification. Putting this idea into practice and developing such a market in the new century requires careful consideration of institutional issues that may ensue. In this last section, we would like to discuss one possible application example and one extension worthy of further discussion in the future.

There could be a variety of reasons for a linked exchange rate to emerge and exist. For example, as a trading and financial center, Hong Kong has adopted a linked exchange rate system of one kind or another throughout most of its history. Since October 17, 1983, the Hong Kong dollar has been officially pegged to the U.S. dollar at the fixed rate of 7.8 Hong Kong dollars to one U.S. dollar (Hong Kong Monetary Authority, 2000). Because of the vitality which the linked exchange rate system brings to the Hong Kong economy, the government is always fully committed to preserving the link. At the end of December 2004, the official foreign currency reserve assets of Hong Kong amounted to US\$123.6 billion, which represents over six times the amount of currency in circulation (Hong Kong Monetary Authority, 2005). It is the world's sixth largest holder of foreign currency reserves, but unlike the first five (Japan, Mainland China, Taiwan, Korea, and India) Hong Kong has no debt of any kind. In fact, the government has never issued bonds of any sort.

Although the linked exchange rate system has enabled Hong Kong to remain unaffected by external shocks and protected its currency resilience against sudden collapse since its establishment, it is not uncommon for confidence in the tenacity and credibility of the link to fall among investors and the general public during times of financial and political instability. In the face of potential "sunspot" events, such as the depreciation of the Japanese Yen and the Asian currency crises, while government determination and (re)assurance might serve to stabilize the market, prospectively a more strategic and proactive undertaking could be the introduction of "pegged" bonds to avoid a self-fulfilling currency crisis. Since the gains to the holders of "pegged" bonds are closely tied to the stability of the linked exchange rate, these holders are more likely to be defenders of the local currency rather than promoters or followers of speculative attacks.

A currency authority like that of Hong Kong possesses ample foreign currency reserves to support its currency value, which makes the risk of currency crisis low (insurable) and the use of "pegged" bonds highly feasible for the situation of Hong Kong. This all said it still requires careful institutional design to make the idea workable. The potential issues deserving of future research includes a clear definition of the trigger event, the arrangement of trust funds, the choice of appropriate coupon rates, the due diligence process, the analysis of default risk, the selection of competent bond underwriters, the involvement of rating agencies, promotion and communication, etc.; all of these are indispensable aspects of a successful Soros bond issuance.

Another possible extension has to do with non-financial catastrophic events embedded in contingent debt forgiveness. On September 21, 1999, central Taiwan experienced a 7.3 earthquake that caused more than 2,000 deaths and billions of dollars in losses. Luckily for Taiwan, this earthquake occurred in a less populated

area with few industries around. If the earthquake had hit the Hsin-Chu Science Park, where 10% of the world's memory chips are produced and 6.9% of Taiwan's GDP is generated, then Taiwan's economy would have been severely hurt. The empirical work by Papadakis and Ziemba (2001) has documented the derivative effects of Taiwan's earthquake on U.S. personal computer manufacturing. As a matter of fact, Taiwan is the world's largest producer of more than 10 information technology products, including notebooks and motherboards (both account for more than two thirds of world production); see Papadakis and Ziemba (2001) and Addison (2001). In line with our discussion, the Science Park of Taiwan should have the incentive to set up a CAT insurance scheme by, for instance, issuing a CAT bond. The firms in the Science Park could distribute a higher coupon rate to bondholders in regular time, and in case a catastrophe occurs the forfeited principal would be quickly available for reconstruction. For practical implementation, the catastrophe is usually defined by an objective standard; for instance, when an earthquake of 7.0 on the Richter scale is measured in the Park area or the output of the Park falls by 40% because of an earthquake, we say that a catastrophe has occurred.

Of course, various factors can cause a 40% drop in output. If China blockades the Taiwan Strait, output may drop more than 40% due to insufficient import inputs. Suppose the Science Park CAT bonds are issued widely around the world. When there is political instability in the Taiwan Strait, bondholders, worried about losing their bond principal, will form a large international pressure group against Mainland China's blockade. This pressure alone might not be large enough to bring about significant change; but it might have a marginal effect. The above scenario is of course hypothetical, but the wild question is: Could the threat of regional security be shared by the global market? For places such as Israel and Taiwan which are surrounded by strong and antagonistic powers, it seems that further thinking along this line is worthwhile.

Finally, in this paper we have only looked at the case of the CAT bond (debt forgiveness) and have not considered other insurance innovations, such as nonindemnity hedges and contingent refinancing discussed in Doherty (1997). In the context of financial crises, perhaps these two alternatives may also generate interesting and insightful results. Research along such lines might also be worthwhile in the future.

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