Strategic Complementarities and The Twin Crises[✧]

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ABSTRACT

The economic literature has emphasized the role of strategic complementarities in generating banking crises and currency crises. Motivated by evidence from recent financial crises, we study a model, where strategic complementarities exist, not only within a group of creditors or within a group of currency speculators, but also between the two groups. The additional type of strategic complementarities generates a vicious cycle between banking crises and currency crises. This vicious cycle magnifies the correlation between the two crises and destabilizes the economy. We discuss some empirical implications and policy implications, and, in particular, show that due to the interaction between the banking sector and the currency market, a Lender of Last Resort might not be able to prevent bank runs.

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1. Introduction

It is well known that strategic complementarities among economic agents may cause financial crises. According to banking-crises theory, due to the fact that banks finance long-term investments with short-term liabilities, an individual creditor is better-off demanding early withdrawal if other creditors do so. This, in turn, may cause a panic among creditors, and may generate a bank run that cannot be explained by economic fundamentals alone (see: Diamond and Dybvig, 1983). Similarly, in currency-crises theory, the willingness of the government to maintain a fixed exchange rate regime decreases with the number of speculators that attack the currency. As a result, the incentive of an individual speculator to attack the currency increases with the number of speculators who do that, and, again, this might lead to a currency attack that is not justified by economic fundamentals (see: Obstfeld, 1996, and Morris and Shin, 1998).

A common feature in all the papers mentioned above is that they look at one group of homogeneous agents – either creditors or speculators – and analyze the consequences of strategic complementarities among members of this group. An interesting case (that was not analyzed in the literature) arises when strategic complementarities exist, not only within a group of creditors or within a group of speculators, but also between the two groups. By this, we mean that the incentive of creditors to run on the bank increases, not only with the number of creditors that run on the bank, but also with the number of speculators that attack the currency. Similarly, the incentive of speculators to attack the currency increases with the number of creditors that run on the bank as well as with the number of speculators that attack the currency.

We believe that such a pattern of strategic complementarities is quite realistic, and can result from some basic features that characterized small open emerging markets in the last two decades. In fact, this pattern was mentioned in two descriptive papers that documented recent financial crises in such markets.[1] In these economies, Governments maintained fixed exchange rate regimes or narrow exchange rate bands, which were obviously vulnerable to speculative attacks. Domestic banks, in these markets, had a mismatch between foreign liabilities and domestic assets and were thus exposed

[1] See Radelet and Sachs (1998) for the case of South East Asia in 1997, and Dornbusch, Goldfajn and Valdes (1995) for the cases of Chile in 1982 and Mexico in 1994.

to (and not hedged against) exchange-rate risks[2]. This basic set-up can generate strategic complementarities between foreign creditors and speculators. (In addition to the strategic complementarities among members of each group.)

Two effects account for these strategic complementarities. First, a currency attack that yields depreciation of the exchange rate reduces the value of banks' investments relative to the value of their liabilities. Knowing that, foreign creditors expect that banks will have fewer resources available to pay their future liabilities, and thus find it more profitable to take their money out immediately, that is, to run on the bank. Second, when foreign creditors run on domestic banks and pull their money out of the economy, they indirectly reduce the amount of foreign reserves that the government has. Then, the government faces a higher cost of defending the currency, and tends to abandon the fixed exchange rate regime in more circumstances. This, in turn, increases the incentive of speculators to attack the currency, as they know that the attack is more likely to succeed.

In this paper, we study a model with two types of agents: foreign creditors and speculators. Due to the features of emerging markets that were described above, our model has strategic complementarities between foreign creditors and speculators (in addition to strategic complementarities within each group). We study the implications that these strategic complementarities have for the realization of both banking crises and currency crises and for the correlation between the two.

A major empirical motivation for this study is the recent evidence on the *twin crises* phenomenon documented by Kaminsky and Reinhart (1999). They show that many international financial crises that occurred during the 1980's and 1990's included both a massive devaluation and a collapse of the banking system. They find that macroeconomic variables at the root of both of these crises may explain some of the positive correlation between them, however they also point to the existence of a vicious cycle, in which banking and currency problems aggravated each other during that time.

[2] As Krugman (1999) suggested, this exposure can be indirect. In such a case, the assets of the bank can be loans that are denominated in terms of the foreign currency but are extended to domestic firms. Then, depreciation can harm the balance sheets of the domestic firms, which are directly exposed to exchange rate risks. This will harm their solvency and lead to a reduction in the value of bank assets.

In our model, due to strategic complementarities between speculators and creditors, an increase in the probability of one type of crisis generates an increase in the probability of the other type. This yields a vicious cycle between the two types of crisis: a higher probability of bank runs leads to a higher probability of currency attacks, which, in turn, causes the probability of bank runs to increase even more. This vicious cycle can continue on and on - generating higher probabilities of both crises.

Our model shows that in equilibrium, the vicious cycle has two interesting effects. The first effect is a destabilizing effect. There are states of nature, in which a banking crisis occurs just because creditors believe that a currency crisis is going to occur, and a currency crisis occurs just because speculators believe that a banking crisis is going to occur. In these cases, each crisis should not have occurred on its own, but both crises occur as a result of the complementarities between the banking sector and the currency market. The second effect is on the correlation between the two crises. Due to the vicious cycle, both crises become strongly connected to each other, and the result in many cases will be a full correlation between the two crises: Either both crises occur or none of them does.

We analyze other empirical implications of the model and confront them with empirical findings of other recent studies on the twin crises phenomenon.[3] We focus on two issues: The frequency of twin crises relative to regular banking or currency crises, and the costs of twin crises. We show that in our model twin crises are expected to be more frequent in financially liberalized emerging markets than in industrial economies and in developing economies that are not financially liberalized. We also show that in emerging markets twin crises are expected to be more costly than regular banking and currency crises, but this is not necessarily the case in industrial countries. These implications are broadly consistent with the empirical evidence.

Our framework also yields some interesting policy implications. First, as the two crises are strongly connected, our model suggests that a useful way to reduce the probability of one type of crisis is to prevent the other crisis. Thus, an increase in the transaction cost that speculators have to bear when they attack the currency will

[3] See: Bordo, Eichengreen, Klingebiel and Martinez-Peria (2001), Eichengreen and Bordo (2002), Glick and Hutchison (2002), Hoggarth, Reis and Saporta (2002), and Hutchison and Neuberger (2002).

directly reduce the probability of a currency attack, and indirectly reduce the probability of a bank run. Similarly, higher commitment to maintain the fixed exchange rate regime, or lower short-term payoffs to investors will reduce the probabilities of both types of crises. Second, a 'Lender of Last Resort' regime might not achieve its goal of preventing bank runs. Thus, when the government acts as a Lender of Last Resort, it loses more reserves, and increases the probability of a currency crisis. Then, since a currency crisis increases the probability of a banking crisis, the result of a Lender of Last Resort might be a higher probability of a banking crisis. As a result, other policy measures that do not affect the reserves of the government, such as an international Lender of Last Resort (IMF) or suspension of convertibility, may be preferable in the presence of spillovers between the banking sector and the currency market.

Because of strategic complementarities, both banking crises and currency crises, in our model, result from self-fulfilling beliefs. We think this is an important feature since the common view on many recent crises is that the state of the economy that preceded them was not sufficiently bad to justify a crisis without some economic agents believing that a crisis was indeed about to occur. However, unlike most models of self-fulfilling beliefs, our model has a unique equilibrium, in which the fundamentals of the economy uniquely determine whether crises are going to occur or not. This unique equilibrium enables us to derive predictions, which cannot be derived in standard models of self-fulfilling beliefs. Thus, it enables us to characterize endogenous probabilities of both types of crisis, demonstrate the vicious cycle between the two crises, discuss the effect of strategic complementarities on the equilibrium outcomes, and analyze policy measures that can affect the probabilities of crises.

The existence of unique equilibrium in our framework results from the assumption that agents do not have common knowledge about the fundamentals of the economy. Carlsson and van Damme (1993) were the first to show that non-common knowledge generates a unique equilibrium in models of strategic complementarities. Morris and Shin (1998) applied this argument in the context of currency attacks, and Goldstein and Pauzner (2002a) applied it in the context of bank runs. Our paper integrates the banking sector in Goldstein and Pauzner (2002a) with the currency market in Morris and Shin (1998) and studies the twin crises phenomenon, which was not studied in any of these papers. Because of the existence of two groups of agents, the methodology used in our paper to study the equilibrium outcomes is different than the methodologies used by Goldstein and Pauzner and by Morris and Shin. Some of the theoretical tools we use here are based on the recent work of Frankel, Morris and Pauzner (2003), who generalized the basic result of Carlsson and van Damme.[4]

To date, few models have addressed the relationship between currency crises and banking crises. The list includes: Allen and Gale (2000), Burnside, Eichenbaum and Rebelo (2001a, 2001b), Chang and Velasco (2000,2001), Goldfajn and Valdes (1997), Miller (1996,1998a), and Velasco (1987). Miller (1998b) and Marion (1999) provide short surveys. Our paper is different from these papers in three aspects: First, we analyze strategic complementarities between creditors and speculators, whereas the other papers do not look at the interaction between these two groups of strategic agents. Second, we derive firm predictions in a framework of self-fulfilling beliefs. Third, we obtain new results on the occurrence of both types of crises in equilibrium and analyze new policy implications.

The remainder of this paper is organized as follows. Section 2 presents the basic model. In section 3, we analyze the different types of strategic complementarities in our model, and demonstrate the vicious cycle between the two crises. In section 4, we present the equilibrium outcomes. In section 5, we study some empirical implications of the model. In Section 6, we present some policy implications. Section 7 concludes. Proofs are relegated to the Appendix.

2. The Model

Our economy has a banking sector and a currency market. In the banking sector, a continuum [0,1] of foreign creditors holds claims in a commercial bank. Each creditor has to decide whether to demand her money from the bank immediately (i.e. to run on the bank) or to wait. In the currency market, a continuum [0,A] of speculators holds units of the domestic currency *peso*. The exchange rate of the peso against the dollar

[4] The literature that followed Carlsson and van Damme (1993) is known as the global games literature. Other applications in this literature include: Dasgupta (2002), Goldstein and Pauzner (2002b), and Rochet and Vives (2002). For excellent surveys see Morris and Shin (2001, 2002).

(the foreign currency) is initially fixed at 1. The government is committed to maintain this level of the exchange rate and is therefore willing to exchange pesos for dollars at that rate. Each speculator has to decide whether to demand such an exchange (i.e. to attack the domestic currency) or not. In case that many speculators attack the currency, the government might decide to break its commitment and to let the market determine the level of the exchange rate.

Agents from both groups are risk neutral and thus choose their actions so as to maximize their expected payoffs.[5] Each agent makes her decision after receiving a private signal about the state of the economy. (We assume that agents make their decisions simultaneously.) This state, which is denoted as θ and will be referred to as the *fundamentals of the economy*, affects the prospects of the bank and the prospects of the currency in the same direction. It can represent either the terms of trade or the level of productivity, as both of them - when they improve - strengthen the prospects of the domestic currency and those of the domestic bank[6].

We assume that θ has the (improper) uniform prior over the real line. The value of θ is not publicly reported after it is realized. Instead, each agent from both groups receives a private signal regarding the value of the fundamentals. More specifically, when θ is realized, agent *i* observes a signal $\theta_i=\theta+\sigma\varepsilon_i$, where $\sigma>0$ is a constant and the individual specific noise terms ε_i are independently distributed according to a smooth symmetric density function $g(\cdot)$ (the c.d.f. is denoted as $G(\cdot)$) with mean zero.[7]

Figure 1 depicts the order of events in the economy. We then turn to describe the banking sector and the currency market in more details.

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[5] Because of the risk neutrality, some agents can belong to both groups and still maximize their expected payoffs from each activity without considering the payoff received from the other activity.

[6] The fact that we have a unique variable that affects both the banking sector and the currency market helps to simplify our model. This assumption does not account for our result of complete correlation between banking crises and currency crises (See Section 4).

[7] Improper priors simplify the exposition by allowing us to concentrate on the updated beliefs of creditors and speculators conditional on their signals without taking into account the information contained in the prior distribution. Thus, our results can be seen as the limiting case as the information in the prior density goes to zero. They will go through with a proper prior as long as the information in the private signal is sufficiently more precise than the information in the prior distribution. See Hartigan (1983), Morris and Shin (2002, Section 2), and Corsetti, Dasgupta, Morris and Shin (2003) for more discussion on improper priors and their use in the global games literature.

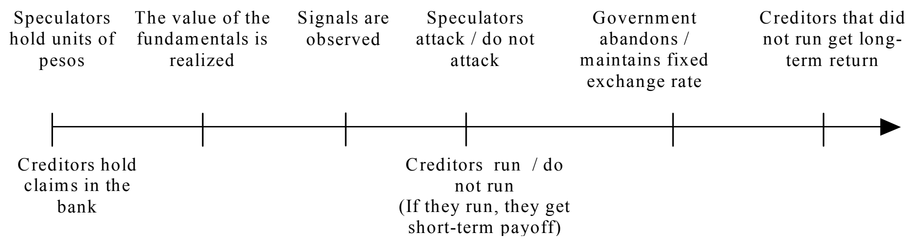

Figure 1: The Order of Events.

The banking sector

In the banking sector, there is one commercial bank and a continuum [0,1] of foreign creditors. Each creditor holds a claim of 1 dollar in the commercial bank. The bank invests the total sum of money in a local long-term asset. The gross return of the asset per each dollar of investment is either $R(\theta,n)$ pesos after maturity (that is, in the long term) or 1 peso in case of an early withdrawal (that is, in the short term). We assume that a portion α of the short-term return is obtained in dollars, and the rest $(1-\alpha)$ is obtained in pesos. This may represent the ability of the bank to sell only a part of the liquidated investment abroad. We also assume that the long-term return R is an increasing function of the state θ, given that the asset is local. It is also a decreasing function of n, the proportion of the investment that is withdrawn early, due to an increasing return to scale on aggregate investment[8].

The loan contract enables creditors to withdraw money from the bank either in the short term or in the long term. In each case, creditors are promised to get the return on their share in the investment at the time of withdrawal. They are promised to get their payoffs in dollars. (We assume that the bank earns no profits.)[9] In order to serve creditors that wish to withdraw money in the short term, the bank has to liquidate a portion of the investment and to exchange the peso-return for dollars with the government. Note that the bank has to exchange $(1-\alpha)$ pesos with the government per each unit of investment that he has to liquidate.

8 Here, increasing returns to scale are the source for strategic complementarities among creditors. We think this is a realistic assumption in the context of a small open emerging market. Such complementarities could also result from lack of liquidity in the short term (see: Diamond and Dybvig, 1983).

9 The assumption that creditors are promised a stochastic return in the long term is made for simplicity. The case of fixed long-term promised return would not change the results of the model.

Since the exchange rate is initially fixed at 1, creditors know that they can get 1 dollar from the bank if they withdraw immediately (in the short term). If they wait, the level of the exchange rate might change and affect their payoff. Denoting the level of the exchange rate (i.e. the price of one dollar in terms of pesos) in the long term as *e*, the long-term payoff of creditors will be $\hat{R}(\theta,n,e)$ dollars, where:

$$\hat{R}(\theta,n,e)=\frac{R(\theta,n)}{e} \quad .$$

Clearly, $\hat{R}(\theta,n,e)$ is an increasing function of the fundamentals of the economy and a decreasing function of the proportion *n* of creditors that decide to withdraw early. Moreover, It is also a decreasing function of the level of the exchange rate *e*, since in case of depreciation, the long-term value of the bank's asset in terms of dollars will decrease.[10]

Each creditor has to decide whether to withdraw her money from the bank immediately (that is, to run on the bank) or to wait until the long term. Creditors will choose the action that yields a higher expected payoff. Clearly, the decision depends on what they believe other creditors and speculators are going to do.

We assume the existence of $\underline{\theta}_B$ and $\overline{\theta}_B$: $\underline{\theta}_B<\overline{\theta}_B$, such that $\hat{R}(\theta,n,e)<1$ for each $\theta<\underline{\theta}_B$ and for each *n* and *e*, and $\hat{R}(\theta,n,e)>1$ for each $\theta>\overline{\theta}_B$ and for each *n* and *e*. (As we note below, *e* has a lower bound and an upper bound.) Thus, when the level of fundamentals is below $\underline{\theta}_B$ (in the lower dominance region), creditors are always better off running on the bank, no matter what they believe other creditors or other speculators are going to do. Similarly, when the level of fundamentals is above $\overline{\theta}_B$ (in the upper dominance region), creditors are always better off waiting for the long term. Then, since θ is uniformly distributed on the real line, there exist signals, at which creditors choose to run independently of their beliefs regarding other agents' behavior, and signals, at which they choose not to run independently of their beliefs.

[10] Here, the negative effect of the exchange rate on the long-term payoff is a result of the assumption that the return of the asset is denominated in pesos. However, such an effect can exist even when the bank holds a local asset, whose value is denominated in dollars. See Footnote 2.

The currency market

The government is committed to maintain the domestic currency's exchange rate *e* at a fixed level of 1. The government will keep this commitment as long as the benefit from maintaining the fixed exchange rate exceeds the cost of doing that. If the government decides to abandon the fixed exchange rate, it will let the currency market determine the new level of the exchange rate. In such cases, *e* will equal $f(\theta)$, where f is a decreasing function of the fundamentals (that is, the currency tends to appreciate when economic conditions improve). We assume that $1<f(\theta)<\bar{e}$ for every θ, that is, the market level of the exchange rate is bounded from above and from below, and the government initially fixes the exchange rate at an over-appreciated level.

We denote the benefit that the government derives from maintaining the fixed exchange rate as *v*. This benefit results from credibility that the government gains when it keeps its commitment. The cost of maintaining the fixed rate is denoted as *c*. We follow Obstfeld (1996) and Morris and Shin (1998) and assume that this cost depends positively on two parameters. The first is the macroeconomic misalignment that is generated by the fixed exchange rate regime. This misalignment is greater when the difference between the market level of the exchange rate and the fixed level of the exchange rate is higher. As a result, *c* is a decreasing function of θ. The second parameter that has a positive effect on *c* is the amount of foreign reserves that the government loses when it defends the exchange rate. Thus, the government has some target level of reserves, which is essential in order to maintain the fixed exchange rate regime. When the difference between this target level and the actual level of reserves is higher, the cost of maintaining the regime becomes higher as well.

In our model, the demand for the foreign reserves of the government originates from two sources: The first is the bank that has to serve early withdrawals (recall that the bank does not have enough dollars to pay creditors in the short term, and thus it has to buy some dollars from the government), and the second is the speculators that attack the currency. We denote the proportion of speculators that attack the currency as *m*. We also know that the demand of the bank for foreign reserves in the short term increases with *n* (it equals $(1-\alpha)n$). Eventually, we get that $c=c(\theta,m,n)$, where $\partial c/\partial\theta<0$, $\partial c/\partial m>0$, and $\partial c/\partial n>0$.

Then, the government will maintain the fixed exchange rate regime if and only if:

$$v - c(\theta, m, n) > 0.$$

That is, if and only if $m(\theta,n)$, i.e. the proportion of speculators that attack the currency at the level of fundamentals θ and the level of capital outflows n, is lower than $m^*(\theta,n)$, which is given by:

$$v - c\left(\theta, m^*(\theta, n), n\right) = 0.$$

Finally, the level of the exchange rate e will be determined by the following function:

$$e(\theta, n, m) = \begin{cases} 1 & \text{if} \quad m < m^*(\theta, n) \\ f(\theta) & \text{if} \quad m \geq m^*(\theta, n) \end{cases}.$$

Note that $m^*(\theta,n)$ is an increasing function of θ and a decreasing function of n. Thus, $e(\theta, n, m)$ is weakly decreasing in θ and weakly increasing in m and in n.

We now turn to describe the speculators. As we mentioned earlier, there is a continuum [0,A] of speculators. Each speculator holds one unit of peso and has to decide whether to attack the currency or not. The net payoff of a speculator that attacks the currency in terms of dollars is given by:[11]

$$a(\theta, m, n) = 1 - \frac{1}{e(\theta, m, n)} - t.$$

Here, the benefit from the attack in terms of dollars is $1 - \frac{1}{e(\theta,m,n)}$, which captures the change in the level of the exchange rate following the attack. This benefit is zero if the government maintains the fixed exchange rate regime, and positive otherwise. The cost of the attack in terms of dollars is $t>0$. A speculator that does not attack the currency simply gets 0. Each speculator will choose the action that yields the highest expected payoff. (Again, the decision of speculators depends on their beliefs regarding the behavior of other agents.)

[11] By writing the net payoff in terms of dollars, we implicitly assume that speculators are foreigners. The analysis will not change in case those speculators are local residents.

We assume the existence of $\underline{\theta}_C$ and $\overline{\theta}_C$: $\underline{\theta}_C < \overline{\theta}_C$, such that $c(\underline{\theta}_C, 0, 0) = v$ and $f(\overline{\theta}_C) = 1 + t$. As a result, when the level of fundamentals is below $\underline{\theta}_C$, speculators are always better off attacking the currency, no matter what they believe other speculators or other creditors are going to do. Similarly, when the level of fundamentals is above $\overline{\theta}_C$, speculators are always better off not attacking. Again, since θ is uniformly distributed on the real line, there exist signals, at which speculators choose to attack independently of their beliefs regarding other agents' behavior, and signals, at which they choose not to attack independently of their beliefs.

3. Strategic Complementarities and the Vicious Cycle

Our model has two types of strategic complementarities. First, there are strategic complementarities within each group of agents. In the banking sector, due to the increasing returns to scale on the investment held by the bank, the incentive of each creditor to withdraw her money early is higher when more creditors withdraw early. In the currency market, since the cost of defending the currency increases when the government has fewer reserves left, the incentive of each speculator to attack the currency is higher when more speculators attack the currency.

Second, there are also strategic complementarities between the two groups of agents. Since the bank has a mismatch between foreign liabilities and domestic assets, its prospects will deteriorate when the probability of depreciation is higher. As a result, the incentive of creditors to run on the bank increases with the number of speculators that attack the currency. In the other direction, when foreign creditors demand early withdrawal, the bank has to exchange pesos for dollars with the government. This reduces the amount of reserves that the government has, and increases the incentive of speculators to attack the currency. The result of these strategic complementarities is that when speculators attack the currency, they 'effectively' also run on the bank, although they attack for different reasons. Similarly, when creditors run on the bank, they 'effectively' also attack the currency.

In this paper, we are interested mainly in the second type of strategic complementarities, that is, in the complementarities between the two groups. As we show below, this type of strategic complementarities generates a vicious cycle between banking crises and currency crises. In the rest of this section we analyze the strategies of agents in our model, and show how their strategies lead to the vicious cycle.

We start by looking at threshold strategies. Suppose that all speculators use the same threshold strategy: They all attack the currency if they observe a signal below θ_C, and they do not attack if they observe a signal above θ_C. As we show in the Appendix, given these strategies, creditors will also coordinate on a threshold strategy: They will run on the bank if they observe a signal below θ_B, and will not run if they observe a signal above θ_B. Moreover, as we also show in the Appendix, for each θ_C that characterizes the behavior of speculators, there is a unique θ_B that characterizes the behavior of creditors. As a result, we can define a function $\theta_B(\theta_C)$ that determines the threshold strategy played by creditors for each threshold strategy that is played by speculators.

We now turn to characterize this function. We know that under the belief that speculators act according to the threshold signal θ_C, creditors will coordinate on playing according to θ_B. Now, consider a creditor that observes the signal θ_B and believes that other creditors play a threshold strategy characterized by the signal θ_B, and that speculators play a threshold strategy characterized by θ_C. Due to continuity, this creditor will be indifferent between running and not running. Thus, observing this signal, the payoff she will get from running on the bank (1 dollar) is equal to the expected payoff from waiting until the long term. Given the structure of information, this yields the following equation:

$$\int_{-\infty}^{\infty}\left[\hat{R}\left(\theta, G\left(\tfrac{\theta_B-\theta}{\sigma}\right), e\left(\theta, G\left(\tfrac{\theta_B-\theta}{\sigma}\right), G\left(\tfrac{\theta_C-\theta}{\sigma}\right)\right)\right)-1\right]\frac{1}{\sigma}g\left(\tfrac{\theta_B-\theta}{\sigma}\right)d\theta = 0\,.$$

Here, conditional on the signal θ_B, the posterior density over θ is $\frac{1}{\sigma}g\left(\frac{\theta_B-\theta}{\sigma}\right)$. Then, given the state θ, the proportion of creditors that run on the bank when they play a threshold strategy characterized by θ_B is $n(\theta,\theta_B)=G\left(\frac{\theta_B-\theta}{\sigma}\right)$. Similarly, the proportion of speculators that attack the currency when they play a threshold strategy characterized by θ_C is $m(\theta,\theta_C)=G\left(\frac{\theta_C-\theta}{\sigma}\right)$. Changing the variable of integration, we can get the following equation that implicitly characterizes $\theta_B(\theta_C)$:

$$\int_0^1 \left[\hat{R}\left(\theta_B - G^{-1}(n)\sigma, n, e\left(\theta_B - G^{-1}(n)\sigma, n, G\left(G^{-1}(n) + \tfrac{\theta_C - \theta_B}{\sigma}\right)\right)\right) - 1\right] dn = 0 .$$

Similarly, we define a function $\theta_C(\theta_B)$ that determines the threshold strategy played by speculators for each threshold strategy that is played by creditors. This function is implicitly characterized by the following equation:

$$\int_0^1 a\left(\theta_C - G^{-1}(m)\sigma, m, G\left(G^{-1}(m) + \tfrac{\theta_B - \theta_C}{\sigma}\right)\right) dm = 0 .$$

Proposition 1 studies an important feature of the two functions: $\theta_B(\theta_C)$ and $\theta_C(\theta_B)$.

PROPOSITION 1: Both $\theta_B(\theta_C)$ and $\theta_C(\theta_B)$ are weakly increasing.

The implication of Proposition 1 is the following: When creditors believe that speculators attack the currency in more circumstances, they will run on the bank in more cases. Similarly, when speculators believe that creditors run on the bank in more circumstances, they will attack the currency more. This property is a result of the strategic complementarities between creditors and speculators. This property lays the ground for the vicious cycle between banking crises and currency crises.

Before we turn to describe the vicious cycle, we define four fundamental threshold signals that characterize the behavior of agents under extreme beliefs: Threshold θ_C^* characterizes the behavior of speculators when they believe that creditors never run on the bank, that is that n=0. It is defined by the following equation: $\int_0^1 a\left(\theta_C^* - G^{-1}(m)\sigma, m, 0\right) dm = 0$. Similarly, threshold θ_C^{**} characterizes the behavior of speculators when they believe that n=1, threshold θ_B^* characterizes the behavior of creditors when they believe that m=0, and threshold θ_B^{**} characterizes the behavior of creditors when they believe that m=1. The equations that define θ_C^{**}, θ_B^*, and θ_B^{**} are analogous to the equation that defines θ_C^*. Following Proposition 1, we know that $\theta_B^* \leq \theta_B^{**}$ and $\theta_C^* \leq \theta_C^{**}$.

In order to demonstrate the vicious cycle between the two types of crises, we use Figure 2. As we see in the figure, as θ_C becomes small, $\theta_B(\theta_C)$ converges to θ_B^*. This is because creditors become more and more positive that speculators will not attack the currency. Similarly, as θ_C becomes large, $\theta_B(\theta_C)$ converges to θ_B^{**}. As we showed in Proposition 1, overall, $\theta_B(\theta_C)$ increases in θ_C: As θ_C increases and more speculators attack the currency, the level of signal that makes creditors indifferent has to increase in order to compensate them for the higher probability of depreciation. The shape of $\theta_C(\theta_B)$ is analogous to that of $\theta_B(\theta_C)$.

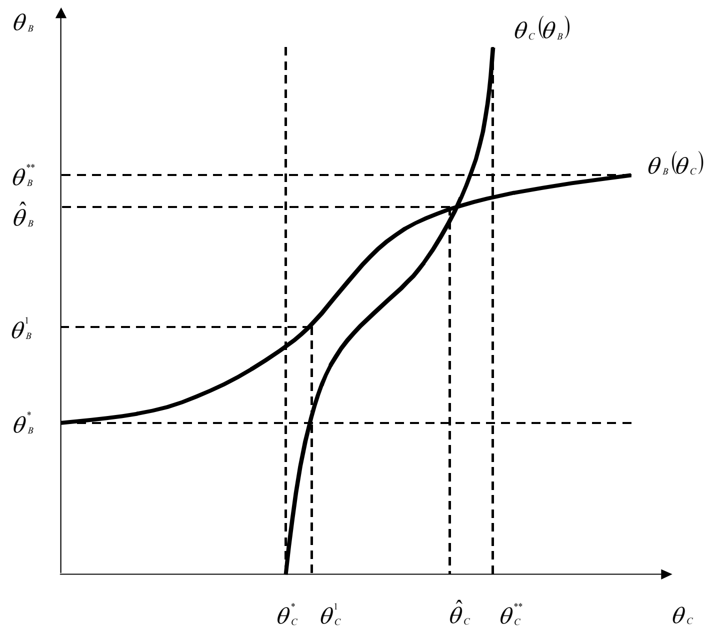

Figure 2: Threshold Strategies

Then, as the figure shows, the vicious cycle between the two crises goes as follows: Suppose that creditors believe that θ_C=-∞, in this case, they will coordinate on a threshold signal: $\theta_B=\theta_B^*$. Then, given that $\theta_B=\theta_B^*$, speculators will act according to a higher threshold signal; this threshold signal is $\theta_C(\theta_B^*)$, which is denoted as θ_C^1 in the figure. Now, creditors will have to update their beliefs about the behavior of speculators. Given the new threshold signal that characterizes the behavior of speculators, creditors will now set θ_B to be equal to $\theta_B(\theta_C(\theta_B^*))$, which is denoted as θ_B^1. This vicious cycle, where both θ_B and θ_C are updated upwards will continue on and on.

Eventually, as we show later, we will get to an equilibrium point $\{\hat{\theta}_B, \hat{\theta}_C\}$, where $\theta_C(\hat{\theta}_B) = \hat{\theta}_C$ and $\theta_B(\hat{\theta}_C) = \hat{\theta}_B$. At this point, the process will stop.

To sum up, due to strategic complementarities between creditors and speculators, we observe a pattern where bank runs and currency attacks strengthen each other: When creditors believe that speculators will attack the currency with a higher probability, they will tend to run more on the bank. This, in turn, will cause speculators to attack the currency even more, and so on.

4. Equilibrium Outcomes and Correlation between Crises

We now turn to analyze the equilibrium outcome. As we noted above, a threshold equilibrium is characterized by two threshold signals $\hat{\theta}_B$ and $\hat{\theta}_C$ that satisfy the equations: $\theta_C(\hat{\theta}_B) = \hat{\theta}_C$ and $\theta_B(\hat{\theta}_C) = \hat{\theta}_B$. The point $\{\hat{\theta}_B, \hat{\theta}_C\}$ is the fixed point, to which the vicious cycle we described in Section 3 converges. As we show in the Appendix, our model has a unique threshold equilibrium. Moreover, this equilibrium is the only possible equilibrium in our model.[12] Importantly, the proof of uniqueness here is different from the one in most papers in the global games literature (for example: Morris and Shin, 1998, and Goldstein and Pauzner, 2002a), since we have two groups of agents, and thus two threshold signals in equilibrium.

Knowing the equilibrium strategies of agents, and taking account of the fact that we have two continuums of agents, we can calculate the proportion of creditors that run on the bank and the proportion of speculators that attack the currency for each realization of θ. This, in turn, enables us to tell which crisis is going to occur at each level of the fundamentals. In order to get a simple characterization, we will focus on the case where σ approaches 0. In this case, the aggregate behavior of agents in equilibrium is approximately the following: All creditors run on the bank when θ is below $\hat{\theta}_B$ and none of them does so when θ is above $\hat{\theta}_B$; All speculators attack the currency when θ is below $\hat{\theta}_C$ and none of them does so when θ is above this level. Then, as noted by Corsetti, Dasgupta, Morris and Shin (2003), comparative statics on the prior probabil-

[12] In the appendix, we solve for equilibrium strategies and show that our threshold equilibrium is the only equilibrium in the model. Another property of this equilibrium is that it is the result of elimination of pareto dominated strategies. Since this is not the focus of the paper, we do not prove this property.

ity of a bank run (currency attack) can be reduced to the behavior of $\hat{\theta}_B$ ($\hat{\theta}_C$). Thus, this framework is convenient for deriving predictions on the probabilities of banking and currency crises although we are using an improper prior.[13]

As it turns out, the equilibrium outcome depends on the ranking of the four threshold signals: θ_B^*, θ_C^*, θ_B^{**}, and θ_C^{**}. Proposition 2 characterizes the equilibrium outcome in the case where $\theta_B^* < \theta_C^* < \theta_B^{**} < \theta_C^{**}$. This proposition demonstrates two interesting effects of the vicious cycle: its effect on the correlation between the two crises and its destabilizing effect on the economy. The equilibrium outcome is also illustrated in Figure 3. Importantly, similar qualitative results will be obtained for other three of the possible rankings ($\theta_B^* < \theta_C^* < \theta_C^{**} < \theta_B^{**}$; $\theta_C^* < \theta_B^* < \theta_C^{**} < \theta_B^{**}$; and $\theta_C^* < \theta_B^* < \theta_B^{**} < \theta_C^{**}$). The other (only) two possible rankings ($\theta_B^* < \theta_B^{**} < \theta_C^* < \theta_C^{**}$ and $\theta_C^* < \theta_C^{**} < \theta_B^* < \theta_B^{**}$) yield a weaker form of interdependence between banking crises and currency crises.[14]

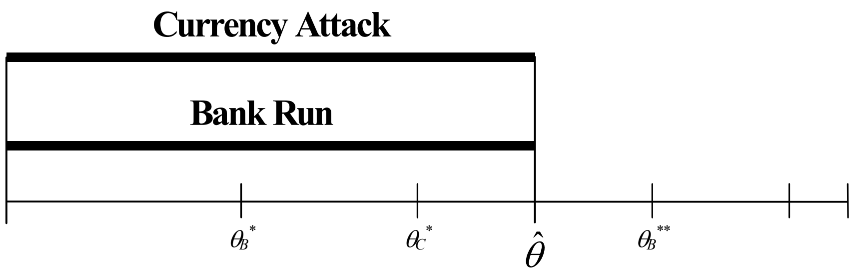

Figure 3: The Realization of Bank Runs and Currency Attacks in Equilibrium. (The case where $\theta_B^* < \theta_C^* < \theta_B^{**} < \theta_C^{**}$ and σ approaches 0.)

PROPOSITION 2: In the case where $\theta_B^* < \theta_C^* < \theta_B^{**} < \theta_C^{**}$ and σ approaches 0:

a) $\hat{\theta}_B$ and $\hat{\theta}_C$ converge to a single value: $\hat{\theta}$.

b) $\hat{\theta}$ is between θ_C^* and θ_B^{**}.

[13] As Corsetti, Dasgupta, Morris and Shin (2003) note: When the signals received by agents are very precise relative to the information in the prior, a uniform prior over θ serves as a good approximation in generating the conditional beliefs of agents. Then, the equilibrium obtained under the uniform prior will be a good approximation to the true equilibrium. Thus, if we can say something about the state θ under which a crisis happens, then we may give an approximate answer to the ex ante probability of a crisis by evaluating the prior distribution $H(\theta)$ at this state.

[14] The ranking of the threshold signals is determined by the exogenous parameters and functions: t, v, $R(\bullet)$, $f(\bullet)$, and $c(\bullet)$. We ignore cases, in which two or more of these threshold signals equal each other.

The first interesting implication of the vicious cycle is its effect on the correlation between the two crises. As we can learn from Figure 3, the case that is studied in Proposition 2 yields complete correlation between banking crises and currency crises. Thus, in equilibrium, either both crises occur or none of them does. This complete correlation is a result of the vicious cycle between the two types of crises. Thus, as a result of the spillovers between the two types of crises, both crises become strongly connected, and always happen together.

It is important to note that the complete correlation is not a result of the fact that both crises are affected by the same fundamentals (θ). Without the existence of spillovers between the two crises, a banking crisis would have occurred below θ_B^*, and a currency crisis would have occurred below θ_C^*. While this case generates some positive correlation between the two crises, it does not yield a complete correlation (since $\theta_B^* < \theta_C^*$). Thus, as Kaminsky and Reinhart (1999) observed in the data, there are two sources for the correlation between the two crises: The first is the common macroeconomic fundamentals behind the two crises, and the second is the vicious cycle between them. In our model, the first source generates some positive correlation between the two crises, and the other magnifies this correlation and makes it complete.

The other interesting implication of the vicious cycle is the destabilizing effect that it has on the economy. As we can see from Figure 3, in the range of fundamentals between θ_C^* and $\hat{\theta}$, both crises occur. However, in this range, each crisis occurs just because agents believe that the other crisis is going to occur. Thus, since this range is above θ_B^*, creditors that observe signals in this range will not run on the bank if they think that speculators are not going to attack the currency; similarly, since this range is above θ_C^*, speculators that observe signals in this range will attack only if they think that creditors are going to run on the bank. To sum up, in this range, each crisis should not have occurred on its own, however both crises occur just because of the strategic complementarities between speculators and creditors.

5. Empirical Implications

The strong correlation between banking crises and currency crises in our model is broadly consistent with the twin crises phenomenon documented by Kaminsky and Reinhart (1999). Since the phenomenon was first documented, the empirical literature on twin crises has grown and produced more related findings. In this section we confront some implications of our model with some of the empirical findings in the literature. We analyze findings on two basic issues that were investigated in the empirical literature: 1. How frequent are twin crises relative to regular banking crises (that is, banking crises that are not accompanied by currency crises) and regular currency crises (that is, currency crises that are not accompanied by banking crises)? 2. What are the costs generated by twin crises relative to the costs generated by regular banking or currency crises?

The Frequency of Twin Crises

The empirical literature has mostly found that the frequency of twin crises relative to regular banking or currency crises is high in financially liberalized emerging markets. This relative frequency is much lower in industrial economies or in developing economies that are not financially liberalized. This finding is the main conclusion of the study by Glick and Hutchison (2002), and it is also supported by Eichengreen and Bordo (2002) and Bordo, Eichengreen, Klingebiel and Martinez-Peria (2001). Kaminsky and Reinhart (1999) have also pointed to the strong connection between financial liberalization and the twin crises phenomenon. They conclude that during the 1970s, when financial markets were highly regulated, there was no apparent link between banking crises and currency crises, but the two became closely entwined in the 1980s following the liberalization of financial markets across many parts of the world.

Our model is consistent with these findings. In the model, two factors account for the correlation between banking crises and currency crises (which determines the frequency of twin crises). The first factor is the common fundamental θ, which affects the prospects of the bank and the prospects of the currency in the same direction. The second factor is the vicious cycle between the two crises, according to which the occurrence of a banking crisis increases the likelihood of a currency crisis (θ_B has a positive effect on θ_C), and vice versa. In the model, the vicious cycle is generated by the dependence of the country on foreign loans denominated in terms of the foreign currency. These loans lead to the currency mismatch that generates the effect of a currency crisis on the probability of a banking crisis, and they also lead to the loss of reserves that follows a banking crisis and affects the probability of a currency crisis.

Thus, when the country does not depend on these loans, the correlation between the two crises will be caused only by the common fundamental θ, and will be smaller. The dependence on loans denominated in foreign currency is typical to financially liberalized emerging markets. It is less typical to industrial economies and to developing economies that are not financially liberalized. Thus, in our model, financially liberalized emerging markets are expected to exhibit more twin crises.

For example, consider the case studied in Proposition 2. A complete correlation between banking crises and currency crises is obtained there as a result of the strong positive effect that the occurrence of one crisis has on the probability of the other crisis. This effect is a result of the dependence on foreign liabilities, which is typical to financially liberalized emerging markets. If such an effect had not existed (the case of industrial economies), a currency crisis would have occurred below θ_C^* and a banking crisis would have occurred below θ_B^*. As a result, the correlation between the two crises would have been smaller.

The Costs of twin crises

Many researchers have analyzed the costs of twin crises and compared them with the costs of regular banking crises or with the costs of regular currency crises. In most cases, twin crises have been shown to generate higher costs than either a regular banking crisis or a regular currency crisis. Kaminsky and Reinhart (1999), for example, show that, on average, the cost of bailout that follows a twin crisis (13.3% of GDP) is much higher than the cost that follows a regular banking crisis (5.1% of GDP). Similarly, in their sample, the loss of reserves that follows a twin crisis (25.4% of total reserves) is much higher than the loss of reserves that follows a regular currency crisis (8.3% of total reserves). Hoggarth, Reis and Saporta (2002) analyzed the costs of twin crises and regular banking crises in terms of fiscal costs and output loss, and also found that twin crises are generally more costly than regular banking crises. Interestingly, they show that this pattern holds very strongly in emerging markets but not in developed economies.

Since a twin crisis involves a banking crisis and a currency crisis, a natural way to assess its severity is by comparing its costs with the sum of the costs of a regular banking crisis and those of a regular currency crisis. If the costs of a twin crisis are higher, it means that there are additional interactive effects associated with twin crises that damage the economy beyond the damage that is generated by regular banking and currency crises. Evidence provided by Eichengreen and Bordo (2002) suggest that in emerging markets, during the period 1973-1997, the loss of output following a twin crisis was, on average, higher than the loss that followed a regular banking crisis plus the loss that followed a regular currency crisis. The case of industrial economies is different: There, on average, the costs of a twin crisis were not higher than the sum of the costs of a banking crisis and the costs of a currency crisis. Hutchison and Neuberger (2002), who looked at the same question, did not find any evidence to support the hypothesis that the occurrence of a twin crisis exerts an additional significant cost beyond the sum of the costs of each of the crises alone.

To address this issue in our model, we need to find a measure for the severity of a crisis. A natural measure for the severity of a banking crisis is n – the number of creditors that run on the bank. When n is higher, more long-term projects are being liquidated, and thus the loss of output is expected to be higher. Also, if the government bails out the bank, the fiscal costs associated with the bail out will be higher when more creditors run on the bank.[15] Similarly, a natural measure for the severity of a currency crisis is m – the number of speculators that attack the currency.

Then, according to Proposition 1, due to the vicious cycle between banking crises and currency crises, for each level of θ, when more creditors run on the bank, more speculators will attack the currency, and vice versa. Thus, banking crises will be more severe when they are accompanied by currency crises, and vice versa. As a result, the costs generated by twin crises are expected to be higher than the costs of regular banking crises, the costs of regular currency crises, and the sum of the two. Interestingly, in the model, this pattern is a result of the vicious cycle between banking crises

[15] The case of a lender of last resort is studied in the next section.

and currency crises. Thus, as we explained above, the pattern is more likely to hold in financially liberalized emerging markets. In developed countries, on the other hand, the occurrence of a currency crisis is not expected to affect the severity of a banking crisis, and vice versa, and thus the crises will not be more costly when they happen together. These results are consistent with the findings of Kaminsky and Reinhart (1999), Hoggarth, Reis and Saporta (2002), and Eichengreen and Bordo (2002).

The Causes of Twin Crises

In addition to the effect of financial liberalization on the likelihood of twin crises, the empirical literature analyzed other factors that affect the likelihood of these crises. For example: Eichengreen and Bordo (2002) found that the strength of the commitment to a fixed exchange rate regime has a negative effect on the likelihood of twin crises. Kaminsky and Reinhart (1999) found that low international reserves and expansion of bank credit have a positive effect on the likelihood of twin crises. These factors and others are consistent with our model, and have already been discussed in the theoretical literature on banking crises and currency crises. Thus, since they are not unique to the twin crises phenomenon, we do not discuss them here.

6. Policy Implications

The literature on financial crises has proposed many policy measures that may be able to reduce the likelihood of banking crises or currency crises. An interesting implication of our model is that due to the spillovers between the banking sector and the currency market, the overall effect of such policy measures may be more complicated than their simple direct effect. Below, we discuss several standard policy measures that were proposed in the literature, and show how their implications change when the interaction between the banking sector and the currency market is taken into account. Methodologically, we distinguish between policy measures that have a direct effect on the probability of one crisis and those that have a direct effect on the probability of two crises. Throughout the discussion we preserve the basic set up, where the bank has a currency mismatch and the government is committed to a fixed exchange rate regime. While it is important to understand why this basic set up existed in so many emerging markets, this issue is beyond the scope of this paper.

Policy Measures with a Direct Effect on One Crisis – Transaction Costs

Due to the spillovers between the banking sector and the currency market, a basic implication of our model is that policy measures that are usually perceived as helpful in reducing the probability of currency crises can also reduce the probability of banking crises, and vice versa. This effect can be quite significant given the magnifying effect that the vicious cycle has on the probabilities of both crises.

For example, we analyze the effect of t: the transaction cost that speculators have to bear in order to attack the currency. We define a function $\theta_C(\theta_B, t)$ that characterizes the threshold signal that is played by speculators as a function of the threshold signal that is played by creditors and of the transaction cost. As we can learn from the characterization of $\theta_C(\theta_B)$ in Section 3, $\theta_C(\theta_B, t)$ is (weakly) increasing in θ_B and (weakly) decreasing in t. Suppose that at the current level of t, t_0, the following ranking holds: $\theta_B(-\infty)< \theta_C(-\infty, t_0)< \theta_B(\infty)< \theta_C(\infty, t_0)$. (Note that θ_B does not depend on t). Assume also that σ approaches 0. Then, as we show in Proposition 2, both $\hat{\theta}_B$ and $\hat{\theta}_C$ will be between $\theta_C(-\infty, t_0)$ and $\theta_B(\infty)$.

Now, suppose that the government increases t to t_1, and reduces the threshold levels that characterize the behavior of speculators, such that $\theta_C(-\infty, t_1)< \theta_C(\infty, t_1)< \theta_B(-\infty)$. Using arguments similar to the ones in Proposition 2, we can show that in this case, $\hat{\theta}_B$ will be equal to $\theta_B(-\infty)$ and $\hat{\theta}_C$ will be equal to $\theta_C(\infty, t_1)$. Thus, by increasing the transaction cost, the government can directly reduce the probability of a currency attack (as was already noted by Morris and Shin, 1998) and indirectly reduce the probability of a bank run.

Other policy measures that will directly reduce the probability of a currency attack and indirectly reduce the probability of a bank run include: strengthening the commitment to the fixed exchange rate regime (increasing v), and increasing the amount of reserves held by the government (thus, changing the function $c(\bullet)$, such that a loss of reserves will have a smaller effect on the cost of defending the currency). Similarly, policy measures that have a direct effect on the probability of a bank run may indirectly reduce the probability of a currency attack. Such a policy measure could be a decrease in the payment that is promised to creditors in case of an early withdrawal.

Policy Measures with a Direct Effect on Two Crises – Lender of Last Resort

The analysis becomes more complicated when a policy measure has direct effects on the probabilities of both crises, especially if these effects are in opposite directions. Such a policy measure, which is often mentioned as a potential solution to the bank-run problem, is the 'Lender of Last Resort'. In our framework, due to its effect on the likelihood of currency attacks, the effect of this policy measure is ambiguous. We now turn to discuss this issue.

Under a regime of 'Lender of Last Resort' (LOLR), the government commits to lend money to the bank in case of a bank run. Then, the bank will be able to pay creditors that demand early withdrawal, without liquidating the long-term asset. In the bank-run literature, it is known that a LOLR can prevent bank runs[16]. This is because it eliminates the strategic complementarities among creditors. Thus, under a LOLR regime, each creditor knows that even if other creditors withdraw early, the bank will not have to liquidate any asset, and thus her long-term return is not going to be affected.

In our framework, however, when we take into account the effect of a LOLR on the exchange rate, and the effect of the exchange rate on the prospects of the bank, the issue of a LOLR becomes more complicated. First, note that since the liabilities of the bank are in dollars, a LOLR has to lend dollars to the bank in case of a bank run. This, in turn, generates a loss of reserves and an increase in the probability of depreciation. (Note that if the government does not act as a LOLR, there is an indirect loss of $(1-\alpha)$ dollars of reserves per each creditor that runs on the bank. However, when the government acts as a LOLR, the loss of reserves will be 1 dollar per creditor.) Then, since depreciation generates a higher incentive to run on the bank, a LOLR might encourage creditors to run. The key point is that when we take into account the change in the exchange rate, a LOLR does not eliminate the complementarities among creditors, and as a result does not prevent panic-based bank runs. Thus, when more creditors run on the bank, the expected level of the exchange rate is higher, and the incentive of other creditors to run increases. As a result, panic-based bank runs are not prevented, and their probability might even be higher under a LOLR regime.

[16] For example, Rochet and Vives (2002).

In order to demonstrate this point in the simplest possible way, we simplify our framework, and preserve only the ingredients that are essential for the discussion on LOLR. Suppose that the gross return on the asset of the bank per each dollar of investment is either $R(\theta,n,e)$ dollars in the long term or 1 dollar in the short term. (Note that the bank can sell the asset at the short term for dollars. Thus, $\alpha=1$.) Here, θ represents the level of fundamentals, n represents the proportion of the asset that is liquidated in the short term, and e is the level of the exchange rate in the long term. In the spirit of our model, $\partial R/\partial\theta>0$, $\partial R/\partial n<0$, and $\partial R/\partial e<0$. We assume that the level of the exchange rate e depends only on the amount of reserves that the government loses, which is denoted as l. Then, $e=e(l)$, and $\partial e/\partial l>0$. Suppose also that the only players besides the government and the bank are creditors that have to decide whether to withdraw early or not (we have a continuum [0,1] of creditors)[17]. In each case, they can get the current return on their share in the investment. The structure of information remains the same and σ approaches 0. The government is losing reserves only if it acts as a LOLR. We analyze the equilibrium outcome with and without a LOLR.

Without a LOLR, a bank run does not cause any loss of reserves for the government, which means that $l=0$. Strategic complementarities among creditors result from the increasing returns to scale on the investment of the bank. After making the necessary assumptions on the existence of two dominance regions, one can show the existence of a unique threshold equilibrium, where a bank run will occur if and only if the level of the fundamentals is below θ_{NL}. Then, a creditor that observes θ_{NL} will be indifferent under the belief that the proportion of creditors who run is uniformly distributed between 0 and 1. This yields the following characterization of θ_{NL} (for more details, see the derivation of $\theta_B(\theta_C)$ in Section 3):

$$\int_0^1 \left[R\left(\theta_{NL}, x, e(0)\right)-1\right]dx = 0 .$$

With a LOLR, a bank run does not cause any liquidation of the asset, but leads to depreciation that reduces the return in terms of dollars. Then, a bank run will occur if and only if the level of the fundamentals is below θ_L, where θ_L is characterized by:

[17] Here, we chose to ignore speculators and preserve only the basic interaction between the banking sector and the currency market. Adding speculators to the analysis will not change the results.

$$\int_0^1 \left[R(\theta_L, 0, e(x)) - 1\right] dx = 0 \,.$$

From the above two equations, it is not clear whether the probability of a bank run is higher without LOLR or with LOLR. The answer depends on the derivatives of R with respect to n and e, and on the derivative of e with respect to l. Thus, if a loss of reserves is going to generate a huge depreciation and a sharp decrease in the real long-term return of the asset, then LOLR might increase the probability of a bank run.

The analysis suggests that before stating its willingness to act as a LOLR, the government should carefully assess the implications of this policy measure on the currency market. This is not merely because of the adverse effect that a LOLR has on the currency market, but mainly because of the feedback effect that this might have on the bank. As shown above, although a LOLR is meant to prevent bank runs, it might have an opposite effect when the interaction between the banking sector and the currency market is taken into account.

Thus, other policy measures to prevent bank runs may be preferred when a vicious cycle between the banking sector and the currency market exists. An example for such a policy measure is suspension of convertibility. Here, when a bank run happens, the bank suspends liquidation of short-term liabilities. Then, creditors do not have a reason to run on the bank, as they know that long-term projects are not going to be liquidated. As we know from the bank run literature, suspension of convertibility may prevent bank runs, as it eliminates the strategic complementarities between creditors. In addition, when suspension of convertibility is announced, there should not be a direct effect on the probability of a currency attack. Thus, suspension of convertibility can directly reduce the probability of a bank run without generating any feedback effect that might eventually generate an increase in the probability of a bank run.

Another policy measure that can reduce the probability of a bank run without having any feedback effect through the currency market is an international LOLR. Here, an international lender (for example: the IMF) provides liquidity to the bank in case of a bank run, and thus there is no loss of reserves to the government. Thus, the existence of an international LOLR may be extremely important when individual countries are exposed to a vicious cycle between the banking sector and the currency market.

To sum up, the analysis of LOLR demonstrates that before taking a policy measure against one type of crisis, the government should assess the effect that this policy measure has on the probability of the other type of crisis. There are other cases, in which this type of argument may be applied. For example, a policy measure that is often used against currency attacks is an increase in the interest rate that increases the cost of speculation, and reduces the likelihood of an attack. However, an increase in the interest rate also generates an adverse effect on the banking sector, as it makes creditors more eager to run, and thus increases the likelihood of a bank run.

7. Concluding Remarks

In this paper, we studied a model where strategic complementarities between creditors and speculators generate a vicious cycle between banking crises and currency crises. This vicious cycle magnifies the correlation between the two crises and destabilizes the economy. We analyzed empirical and policy implications that are unique to the case of interaction between the banking sector and the currency market, and showed that a Lender of Last Resort might not achieve its goal in such a framework.

In this paper, strategic complementarities between creditors and speculators are the result of foreign liabilities held by domestic banks. Thus, the paper shows that foreign capital might generate some undesirable outcomes. However, one should not conclude that foreign liabilities are not desirable. This is because there are several ways to prevent the vicious cycle without reducing the amount of foreign liabilities.

First, if domestic banks avoid short-term debt contracts that enable creditors to withdraw a fixed amount of money in the short term, there would not be a problem of coordination among creditors, and as a result there would not be a vicious cycle between banking and currency crises. Second, if banks hedged themselves against (direct or indirect) exchange rate risks, the positive impact of depreciation on the probability of a bank run would be prevented, and vicious cycles would not be observed. Third, if governments avoided fixing the exchange rate at an over-appreciated level, speculators would not have an incentive to attack the domestic currency, and the destabilizing effect of depreciation on the banking system would be prevented.

An open question is why, in many recent events, short-term contracts were used, banks did not hedge themselves against exchange rate risks, and governments held non-flexible exchange rate regimes. A potential explanation is that these features might be essential in the case of a small emerging market that is trying to raise capital from abroad. For example, short-term debt contracts could be a result of asymmetric information between foreign lenders and domestic borrowers; lack of hedging could reflect undeveloped financial markets; and non-flexible exchange rate regimes could originate from the need to provide some stability in order to attract foreign capital. However, this paper does not try to provide explanations for the existence of the above features. The purpose of this paper is rather to analyze their consequences.

Appendix

Threshold Strategies

We show that if speculators act according to a threshold strategy characterized by a threshold signal θ_C, creditors will act according to a unique threshold strategy characterized by a threshold signal θ_B. The opposite case is completely analogous.

When speculators act according to threshold signal θ_C, the proportion of speculators that attack the currency at each level of the fundamentals is $G\left(\frac{\theta_C-\theta}{\sigma}\right)$. Then, given n and θ, each creditor that does not run on the bank gets $\hat{R}\left(\theta,n,e\left(\theta,n,G\left(\frac{\theta_C-\theta}{\sigma}\right)\right)\right)$. After taking into account the indirect effect that θ and n have through e, this function is strictly increasing in θ and strictly decreasing in n. Thus, taking into account our assumption on dominance regions, the strategic problem among creditors satisfies the conditions of the strategic problem in Morris and Shin (1998) and Morris and Shin (2002, Section 2.2). As a result, for a given θ_C, there exists a unique θ_B, for which, in (a banking-sector) equilibrium, each creditor will run on the bank if and only if she observes a signal below θ_B. QED.

Proof of Proposition 1

Function $\theta_B(\theta_C)$ is implicitly characterized by the following equation:

$$\int_0^1 \left[\hat{R}\left(\theta_B - G^{-1}(n)\sigma, n, e\left(\theta_B - G^{-1}(n)\sigma, n, G\left(G^{-1}(n) + \tfrac{\theta_C - \theta_B}{\sigma}\right)\right)\right) - 1\right] dn = 0 .$$

Function $\theta_B(\theta_C)$ is then weakly increasing since $e\left(\theta_B - G^{-1}(n)\sigma, n, G\left(G^{-1}(n) + \tfrac{\theta_C - \theta_B}{\sigma}\right)\right)$ is weakly increasing in θ_C and weakly decreasing in θ_B, and since $\hat{R}(\theta, n, e)$ is increasing in θ and decreasing in *e*.

Function $\theta_C(\theta_B)$ is implicitly characterized by the following equation:

$$\int_0^1 a\left(\theta_C - G^{-1}(m)\sigma, m, G\left(G^{-1}(m) + \tfrac{\theta_B - \theta_C}{\sigma}\right)\right) dm = 0 .$$

This function is then weakly increasing because $G\left(G^{-1}(m) + \tfrac{\theta_B - \theta_C}{\sigma}\right)$ is increasing in θ_B and decreasing in θ_C, and because $a(\theta, m, n)$ is weakly decreasing in θ and weakly increasing in *n*. QED.

Existence of Threshold Equilibrium

A threshold equilibrium is characterized by two threshold signals: $\hat{\theta}_B$ and $\hat{\theta}_C$, that satisfy the following equations: $\theta_C\left(\hat{\theta}_B\right) = \hat{\theta}_C$ and $\theta_B\left(\hat{\theta}_C\right) = \hat{\theta}_B$. In order to show that such an equilibrium exists, consider the following series: θ_C^0, θ_B^0, θ_C^1, θ_B^1, …, θ_C^∞, θ_B^∞. Where, θ_C^0 can be any number between -∞ and ∞, and for each $n \geq 0$: $\theta_B^n = \theta_B\left(\theta_C^n\right)$, and $\theta_C^{n+1} = \theta_C\left(\theta_B^n\right)$. A threshold equilibrium will exist if for some $n \geq 0$, $\theta_C^{n+1} = \theta_C^n$. Since both $\theta_B(\theta_C)$ and $\theta_C(\theta_B)$ are weakly increasing, and since both of them are bounded from above and from below (dominance regions), as *n* goes to infinity, θ_C^{n+1} and θ_C^n must converge. QED.

Uniqueness of Threshold Equilibrium

Assume by way of negation that there exist two pairs: $\{\hat{\theta}_B, \hat{\theta}_C\}$ and $\{\hat{\theta}_B^1, \hat{\theta}_C^1\}$, such that $\theta_B\left(\hat{\theta}_C\right) = \hat{\theta}_B$, $\theta_C\left(\hat{\theta}_B\right) = \hat{\theta}_C$, $\theta_C\left(\hat{\theta}_B^1\right) = \hat{\theta}_C^1$, and $\theta_B\left(\hat{\theta}_C^1\right) = \hat{\theta}_B^1$. In addition, either $\hat{\theta}_B \neq \hat{\theta}_B^1$, or $\hat{\theta}_C \neq \hat{\theta}_C^1$. We can immediately eliminate the case where $\hat{\theta}_B \neq \hat{\theta}_B^1$ and $\hat{\theta}_C = \hat{\theta}_C^1$, since this will mean that $\theta_B\left(\hat{\theta}_C\right) = \theta_B\left(\hat{\theta}_C^1\right)$, which is a contradiction to the fact that $\hat{\theta}_B \neq \hat{\theta}_B^1$. Similarly, we can eliminate the case where $\hat{\theta}_B = \hat{\theta}_B^1$ and $\hat{\theta}_C \neq \hat{\theta}_C^1$. Now, assume by way of negation that both $\hat{\theta}_B \neq \hat{\theta}_B^1$ and $\hat{\theta}_C \neq \hat{\theta}_C^1$ hold. Assume also that $\hat{\theta}_B^1 > \hat{\theta}_B$. The equation that characterizes $\hat{\theta}_B$ is

$$\int_0^1 \left[\hat{R}\left(\hat{\theta}_B - G^{-1}(n)\sigma, n, e\left(\hat{\theta}_B - G^{-1}(n)\sigma, n, G\left(G^{-1}(n) + \tfrac{\hat{\theta}_C - \hat{\theta}_B}{\sigma}\right)\right)\right) - 1 \right] dn = 0 \quad \text{(A-1)},$$

and the one for $\hat{\theta}_B^1$ is

$$\int_0^1 \left[\hat{R}\left(\hat{\theta}_B^1 - G^{-1}(n)\sigma, n, e\left(\hat{\theta}_B^1 - G^{-1}(n)\sigma, n, G\left(G^{-1}(n) + \tfrac{\hat{\theta}_C^1 - \hat{\theta}_B^1}{\sigma}\right)\right)\right) - 1 \right] dn = 0 .$$

Due to the properties of $e(\theta, n, m)$ and $\hat{R}(\theta, n, e)$, both equations will hold only if $\hat{\theta}_C^1 - \hat{\theta}_B^1 > \hat{\theta}_C - \hat{\theta}_B$. In particular, this means that $\hat{\theta}_C^1 > \hat{\theta}_C$. However, applying the same logic to find the implications of $\hat{\theta}_C^1 > \hat{\theta}_C$ we get that $\hat{\theta}_B^1 - \hat{\theta}_C^1$ should be higher than $\hat{\theta}_B - \hat{\theta}_C$, which is a contradiction to the condition: $\hat{\theta}_C^1 - \hat{\theta}_B^1 > \hat{\theta}_C - \hat{\theta}_B$. Thus, we rule out the case that $\hat{\theta}_B^1 > \hat{\theta}_B$. Similarly, one can rule out the case that $\hat{\theta}_B^1 < \hat{\theta}_B$. QED.

Broader Uniqueness

Suppose by way of negation that there is a different equilibrium – the alternative equilibrium - in which creditors run on the bank at signals above $\hat{\theta}_B$ (Note that this cannot be a threshold equilibrium). Denote the highest signal, at which creditors switch from running to not running, in the alternative equilibrium, as θ_B^H ($\theta_B^H > \hat{\theta}_B$), and the highest signal, at which speculators switch from running to not running, in the alternative equilibrium, as θ_C^H. Due to the existence of upper dominance regions, θ_B^H and θ_C^H have upper bounds. The equation that characterizes θ_B^H is:

$$\int_{-\infty}^{\infty} \left[\hat{R}\left(\theta, n^A(\theta), e\left(\theta, n^A(\theta), m^A(\theta)\right)\right) - 1 \right] \frac{1}{\sigma} g\left(\tfrac{\theta_B^H - \theta}{\sigma}\right) d\theta = 0 ,$$

where $n^A(\theta)$ and $m^A(\theta)$ represent the behavior of creditors and speculators, respectively, in the alternative equilibrium. Because in the alternative equilibrium, creditors do not run on the bank at signals above θ_B^H, we know that $n^A(\theta) \le G\left(\frac{\theta_B^H-\theta}{\sigma}\right)$. Similarly, we know that $m^A(\theta) \le G\left(\frac{\theta_C^H-\theta}{\sigma}\right)$. Thus,

$$\int_{-\infty}^{\infty}\left[\hat{R}\left(\theta, G\left(\frac{\theta_B^H-\theta}{\sigma}\right), e\left(\theta, G\left(\frac{\theta_B^H-\theta}{\sigma}\right), G\left(\frac{\theta_C^H-\theta}{\sigma}\right)\right)\right)-1\right]\frac{1}{\sigma} g\left(\frac{\theta_B^H-\theta}{\sigma}\right) d\theta \le 0 .$$

Following the same steps we used in Section 3, we know this inequality is equivalent to:

$$\int_{0}^{1}\left[\hat{R}\left(\theta_B^H - G^{-1}(n)\sigma, n, e\left(\theta_B^H - G^{-1}(n)\sigma, n, G\left(G^{-1}(n)+\frac{\theta_C^H-\theta_B^H}{\sigma}\right)\right)\right)-1\right] dn \le 0 .$$

We compare this inequality with the equation implied by the threshold equilibrium: (A-1). Since $\theta_B^H > \hat{\theta}_B$, the two conditions will hold only if $\theta_B^H - \theta_C^H < \hat{\theta}_B - \hat{\theta}_C$. In particular, this means that $\theta_C^H > \hat{\theta}_C$. Now, analyzing the implications of $\theta_C^H > \hat{\theta}_C$ by repeating the line of argument above, we get that this inequality requires $\theta_B^H - \theta_C^H > \hat{\theta}_B - \hat{\theta}_C$, which is of course, a contradiction. Thus, we showed that in equilibrium creditors would not run at signals above $\hat{\theta}_B$. Similarly, we can show that they would run at signals below $\hat{\theta}_B$, and that speculators would act according to the threshold $\hat{\theta}_C$. QED.

Proof of Proposition 2

a) We show that as σ approaches 0, $\hat{\theta}_B^\sigma$ and $\hat{\theta}_C^\sigma$ converge to a single value: $\hat{\theta}$ (the superscript stands for the change in equilibrium thresholds following the change in σ). Suppose, by way of negation, that when σ converges to 0, $\left|\hat{\theta}_B^\sigma - \hat{\theta}_C^\sigma\right|$ is of a higher order than σ. Then, if $\left(\hat{\theta}_B^\sigma - \hat{\theta}_C^\sigma\right)$ is positive, equation (A-1) implies that $\hat{\theta}_B^\sigma$ converges to θ_B^*. Similarly, $\hat{\theta}_C^\sigma$ converges to θ_C^{**}. As a result, $\theta_B^* > \theta_C^{**}$, which is in contradiction to the assumption that $\theta_B^* < \theta_C^* < \theta_B^{**} < \theta_C^{**}$. Similarly, if $\left(\hat{\theta}_B^\sigma - \hat{\theta}_C^\sigma\right)$ is negative,

$\hat{\theta}_B^\sigma$ converges to θ_B^{**} and $\hat{\theta}_C^\sigma$ converges to θ_C^*. As a result, $\theta_C^* > \theta_B^{**}$, which is again in contradiction to the assumption that $\theta_B^* < \theta_C^* < \theta_B^{**} < \theta_C^{**}$. Thus, as σ goes to 0, the difference between $\hat{\theta}_B^\sigma$ and $\hat{\theta}_C^\sigma$ is of an order of σ. Analyzing the two equations that characterize $\hat{\theta}_B^\sigma$ and $\hat{\theta}_C^\sigma$ ($\theta_C(\hat{\theta}_B^\sigma) = \hat{\theta}_C^\sigma$ and $\theta_B(\hat{\theta}_C^\sigma) = \hat{\theta}_B^\sigma$), we can see that $\hat{\theta}_B^\sigma$ and $\hat{\theta}_C^\sigma$ are continuous in σ, and thus small changes in σ as it approaches o have a small effect on $\hat{\theta}_B^\sigma$ and $\hat{\theta}_C^\sigma$. Thus, we can conclude that as σ approaches 0, $\hat{\theta}_B^\sigma$ and $\hat{\theta}_C^\sigma$ converge to a single value: $\hat{\theta}$. QED.

b) We show that $\hat{\theta}_C$ must be higher than θ_C^*. The equation that characterizes $\hat{\theta}_C$ is $\int_0^1 a\left(\hat{\theta}_C - G^{-1}(m)\sigma, m, G\left(G^{-1}(m) + \frac{\hat{\theta}_B - \hat{\theta}_C}{\sigma}\right)\right) dm = 0$, and the one that characterizes θ_C^* is $\int_0^1 a\left(\theta_C^* - G^{-1}(m)\sigma, m, 0\right) dm = 0$. Function $a(\theta, m, n)$ is weakly decreasing in θ, weakly increasing in *n*, and strictly increasing in θ when $a(\theta, m, n) \geq 0$. The expression $G\left(G^{-1}(m) + \frac{\hat{\theta}_B - \hat{\theta}_C}{\sigma}\right)$ is greater than or equal to 0 for all *m* between 0 and 1, and is strictly positive for some values of *m*. Thus, $\hat{\theta}_C$ must be higher than θ_C^*. Similarly, we can show that $\hat{\theta}_B$ must be lower than θ_B^{**}. QED.

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