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Abstract

We study contagion in a model in which financial crises can occur due to both weak fundamentals and adverse self fulfilling expectations. Contagion emerges only if a crisis in one country leads international investors to rationally update beliefs about fundamentals in other countries. But purely expectational crises may be contagious, as investors may infer that fundamentals are weak. Hence the structure of information is crucial. The analysis delivers useful lessons for assessing which countries are more vulnerable to contagion, which types of crises are more infectious, and whether increased transparency ameliorates contagion effects.

1 Introduction

One of the most striking aspects of recent emerging markets crises has been the extent of financial *contagion.* The prominence of contagion has risen to the point of making its explanation a litmus test of competing theories of crises. Theories based solely on weak *fundamentals* have had a very hard time rationalizing how events in Thailand and Russia may have created havoc in Argentina and Mexico, in spite of the insignificance of trade flows or other direct links. This difficulty has convinced many of the superiority of theories based on self fulfilling expectations, animal spirits, and jumps between *multiple equilibria.* However, multiple equilibrium models of crises provide only a feeble explanation of financial contagion, as they are consistent with other outcomes, including the absence of contagion. To explain contagion, existing multiple equilibrium models implicitly assume that a crisis in one country changes how equilibria is selected in others, and that such a change goes in the particular direction of making the selection of bad equilibria more likely. These assumptions seem highly questionable.

In this paper we explore the alternative possibility that contagion may be better explained by *both* fundamentals and self fulfilling beliefs. Our discussion is based on a theoretical model in which the probability of a crisis in any given country depends on foreign investors' beliefs about the distribution of its fundamentals, and also on animal spirits or sunspots. In contrast with existing models, we assume that sunspots are independent across countries, hence avoiding arbitrary assumptions about how a crisis changes equilibrium selection. Instead, contagion occurs if a crisis in one country leads investors to rationally and adversely update their beliefs about fundamentals in other countries. However, purely expectational crises may still be contagious; this is the case if investors cannot determine if the originating crisis has been caused by weak fundamentals or animal spirits. Accordingly, our discussion directs attention to the structure of information available in international capital markets and its relationship with the extent and nature of contagion.

Our analysis yields several lessons of interest. As in the literature, our model implies that a country is more *vulnerable to contagion* if its fundamentals, in particular its financial position, are weak. Perhaps more interestingly, we discuss when a given crisis is more *infectious*, a question that has been ignored in the debate. It turns out that the contagiousness of a crisis depends on the amount of information it releases. If information is sufficient for investors can discern whether the crisis is caused by fundamentals or beliefs, a fundamentals-driven crisis is *more* contagious than a beliefs-driven crisis, and *more* contagious than if information is less complete. This has the interesting policy implication that better information would *not* eliminate contagion. Instead, more *transparency* would make some kinds of crises more contagious and some others less so.

2 A Simple Model of Contagion

Our discussion will be based on a simple model of public debt service, in the spirit of Calvo (1988) and Chang and Majnoni (2001). We consider two small open economies, labeled A and B, during two consecutive periods. As our interest is on how the occurrence of a crisis in one country affects the other, we focus on A's events during the first period, after which we turn attention to B.

For simplicity, assume that the two countries have the same fundamental structure, and begin by describing country A in the first period. The government of A inherits some foreign debt that matures in that period. Concretely, it has an obligation to repay $L_A > 0$ units of an international currency, say dollars, to the debt holders.

At the beginning of the period, government A attempts to roll over its extant debt by selling claims to L_A dollars, payable at the end of the period, in a competitive auction. The bidders in the auction are a continuum of foreign investors, whose opportunity cost of funds is zero within the period. All agents are rational and risk neutral; hence foreign investors will buy A's new debt issue if and only if its price, denoted by q_A, is equal to their subjective probability that the debt will be in fact honored. The auction proceeds, $X_A = q_A L_A$, are transferred immediately to government A.

After the auction takes place, and having received X_A , A's government chooses whether or not to default on its foreign obligations. Defaulting imposes a direct cost, denoted by D_A, on the economy. The cost of default is a random variable that becomes known to the government immediately after the auction. To simplify matters, we assume here that D_A may take only two values, high (D_H) or low (D_L), with $D_H > D_L$. The *unconditional* probability of $D_A = D_L$ will be denoted by p_L. Note that, for purposes of our discussion, the cost of default will be the only *fundamental* source of uncertainty. This restriction is much stronger than needed: randomness in other fundamentals can be straightforwardly introduced. In fact, D_A can be taken to represent any random fundamentals that affect A's default decision.

Rolling over the old debt is assumed to be desirable. To formalize this, assume that, in the absence of default, the new debt sold in the auction is financed with a lump sum tax; in contrast, the old debt not rolled over is financed with the proceeds of some other distortionary tax. Hence, the proceeds of the distortionary tax must be $T_A = z_A L_A - X_A$, where $z_A = 1$ if there is no default, and $z_A = 0$ if government A defaults. Note that, assuming there is no default, the size of the distortionary tax falls as X_A, the revenue from the new debt auction, increases. This is the prime motivation behind the roll over.

Finally, the government maximizes the country's end of period consumption which, given our discussion, is given by $y_A - T_A - F(T_A) - z_A L_A - |z_A - 1| D_A$, where y_A is country A's income in the period, assumed to be exogenously given, and $F(.)$ denotes the excess burden of the distortionary tax; here we simply assume that $F(x) = x^2$.

This completes the description of country A in the first period. Country B in the second period is almost exactly the same save for one crucial difference: in the second period, it is known whether country A experienced a default *crisis* in the first period. Our analysis will therefore focus on whether and how such an event can change the outcomes in country B, that is, whether and how there can be financial *contagion.*

3 Equilibrium

Equilibrium is defined in the usual way. To compute equilibria in the first period, start with government A's default decision. Having observed X_A and the realization of D_A, government A chooses whether to default to maximize A's consumption. A quick calculation reveals that not defaulting is optimal if

$$D_A \geq 2L_A + L_A^2 - 2L_A X_A \tag{1}$$

and defaulting is optimal otherwise. Now, recall that the revenue from selling new debt, $X_A = q_A L_A$, depends on q_A and hence on the foreign investors' probability belief that there will be no default. But government A's default decision itself depends on X_A, as given by 1. To solve for equilibrium outcomes, we impose rational expectations.

Equilibria can be of three types. First, there may be no default irrespectively of the realization of D_A. Under rational expectations, foreign investors recognize this fact and bid the price of the new debt to $q_A = 1$; hence $X_A = L_A$ in this equilibrium. But for this to be an equilibrium, government A must have no incentives to ever default. This requires 1 to hold even if $D_A = D_L$, that is, even if the direct cost of default is low. This means that there is a *never default* equilibrium if and only if

$$D_L \geq 2L_A + L_A^2 - 2L_A^2 = 2L_A - L_A^2 \tag{2}$$

Intuitively, a never default equilibrium exists if the fundamentals are strong enough even if A has bad fundamental luck.

At the other extreme, it may be the case that the government defaults for sure. In this case, investors will not be willing to pay any positive amount for the new debt, and $q_A = X_A = 0$. In this equilibrium, the government chooses to default even if the direct cost of default turns out to be high. This and 1 imply that a *sure default* equilibrium exists if

$$D_H < 2L_A + L_A^2 \tag{3}$$

Finally, it may be that the government defaults only if the cost of the default is low, but does not default if that cost is high. The probability of the latter is $1 - p_L$, which must consequently equal q_A in this *luck of the draw* equilibrium; hence $X_A = (1 - p_L)L_A$. Optimal government behavior and 1 requires

$$D_H \geq 2L_A + L_A^2 - 2L_A^2(1 - p_L) > D_L \tag{4}$$

Which equilibria exist depends on A's parameters, including the initial debt L_A and the distribution of its fundamentals. To illustrate, Figure 1 depicts one possible configuration and identifies some determinants of the probability of a crisis. In the figure, p_L is assumed to be 0.5, and ON, OS, and OD depict the RHS of 2, 3, and 4 respectively.

[INSERT FIGURE 1 HERE]

The never default equilibrium condition 2 is satisfied, and hence never default equilibria exist, if L_A is sufficiently low, that is, between zero and L^N in the figure. Likewise, 3 is satisfied and, hence, sure default equilibria exist if $L_A > L^S$, that is, if L_A is large enough. For intermediate values of L_A, between L^0 and L^1, 4 holds and there is a luck of the draw equilibrium.

The figure reveals that, depending on the economy's parameters, equilibrium may not be unique. If equilibrium is not unique, which one is selected is controversial and there is no accepted way to proceed. But what matters for our analysis is that, given a multiplicity of equilibria, there be some well defined mechanism to coordinate market expectations and select one of the equilibria. For our purposes it is enough to assume that there is an equiprobable random variable that selects one equilibrium. Hence, in the regions of Figure 1 in which there are two equilibria, each one obtains with probability 1/2. This is restrictive but hopefully not too damaging for our purposes. We stress that the "sunspots" variable just introduced has no effect on economic fundamentals: its only role is to coordinate investors' expectations. As a consequence, an unfavorable realization of sunspots can be identified with possibly unjustified but self fulfilling adverse beliefs.

Once one such mechanism for beliefs coordination is specified, the model determines the *ex ante* probability of crisis and default. To illustrate, suppose $L^S < L_A \leq L^1$ in the setting of Figure 1. Then, following A's rollover auction, there are two possible equilibrium continuations: investors may believe that government A will default for sure, making q_A fall to zero and inducing A's government to indeed default regardless of the realization of D; or, investors may believe instead, also correctly, that default will happen only if fundamentals turn out to be weak, which occurs with probability p_L. Given our sunspots assumption, each of these continuations occur with probability one half each, and hence the overall probability of a crisis is $[(1/2) \times 1] + [(1/2) \times p_L]$. Computing the probability of crisis for the other regions of Figure 1 is analogous and straightforward.

Some important conclusions emerge. As emphasized in the literature, the probability of a crisis in country A increases with L_A, the size of $A's$ maturing debt. For our purposes, a more important implication is that, given L_A, the probability of a crisis in A increases with p_L, the prior probability that A's cost of default is low. The intuition, of course, is that a less favorable distribution of A's fundamentals has a negative impact on the likelihood of debt repayment. Knowing this fact, investors lower their bids for A's new debt issue; this increases government A's incentive to default. Also, in Figure 1 OD shifts to the left, increasing the size of the default regions.

Note, finally, that default may be triggered by an unfavorable realization of fundamentals, by self fulfilling expectations, or a combination of both.

In the context of Figure 1, this is clearest if $L^S < L_A \leq L^1$. In that case, adverse expectations (a bad sunspot realization) may drive country A to the sure default equilibrium. If expectations are instead favorable, the economy settles on the luck of the draw continuation; but a crisis still occurs if A's cost of default turns out to be low, that is, if its fundamentals turn out to be bad enough.

Now we turn to country B in the second period. Clearly, the analysis is the same as with country A except for the crucial fact that, at the start of the second period, foreign investors know whether or not a crisis occurred in A in the first period, which may affect their beliefs about B's fundamentals. Hence the one change in the analysis is that foreign investors will condition their behavior at B's debt auction not on the *unconditional* probabilities about $B's$ cost of default but on such probabilities *conditional* on whether there was a crisis in A.

To see how this matters, suppose that A had a crisis in the first period, and ask: what is the *posterior* probability that $D^B = D_L$? Bayes' Rule implies that such a probability, hereon denoted by $\Pr\{D_B = D_L | crisis \text{ in } A\}$, will in general differ from p_L. Since we showed that the probability of a crisis increases with the foreign investors' belief that $D_B = D_L$, it is natural to say that there is *contagion* from A to B if $\Pr\{D_B = D_L | crisis \text{ in } A\} > p_L$, that is, if the investors' beliefs about B's fundamentals deteriorate after observing a crisis in A.

Before turning to the conditions under which contagion is indeed possible, one further assumption should be made and stressed: that sunspots are i.i.d. across time and countries. This not only means that, when multiple equilibria exist, the way an equilibrium is selected in B is the same as in A but, more importantly, that the selection mechanism in B is *independent* of what happened in A. A main implication, as we shall see, is that a crisis in A can infect B only if it leads to a reassessment of the distribution of B's *fundamentals.* This aspect of our study differs sharply from other explanations of contagion based on multiple equilibria, which assume, effectively, that a crisis in one country changes the way an equilibrium is selected in other countries.

4 The Determinants of Contagion

It is straightforward to show that:

$$\begin{aligned} \Pr\{D_B &= D_L | crisis \text{ in } A\} = \Pr\{D_B = D_L | D_A = D_L\}\mu \\ + \Pr\{D_B &= D_L | D_A = D_H\}(1-\mu) \end{aligned} \tag{5}$$

where $\mu \equiv \Pr\{D_A = D_L | crisis \text{ in } A\}$. This is a simple but illuminating expression that identifies how a crisis in A is transmitted to B. Two relationships are key: the statistical relation between the fundamentals in A and B, as captured by $\Pr\{D_B = D_L | D_A = D_L\}$ and $\Pr\{D_B = D_L | D_A = D_H\}$, and what foreign investors infer about $A's$ fundamentals after observing a crisis in A, which is given by μ.

To appreciate the former, suppose that the fundamentals in A and B are independent. In that case, $\Pr\{D_B = D_L | D_A = D_L\} = \Pr\{D_B = D_L | D_A = D_H\} = p_L$, and 5 implies that $\Pr\{D_B = D_L | crisis \text{ in } A\} = p_L$. Hence there can be *no* contagion if fundamentals are independent across countries.

It is natural to conjecture that there is a positive association between fundamentals, in the sense that $\Pr\{D_B = D_L | D_A = D_L\} > p_L > \Pr\{D_B = D_L | D_A = D_H\}$. Under such assumption, contagion is possible. However, 5 also implies that the strength of the relation between A and B's fundamentals is not sufficient by itself to determine if there can be contagion from A to B: the inferences that investors draw from observing a crisis in A also matter. And such inferences depend delicately on the information that is released by a "crisis," which we have not yet specified precisely. To analyze this issue, consider two cases in turn.

Case i: Suppose that, at the beginning of period 2, the *only* information available about period 1's outcomes in A is whether or not a crisis occurred there. In that case, observing a crisis may be a *noisy* indicator of $A's$ fundamentals.

Consider again, for concreteness, the region $L^S < L_A \leq L^1$ in the context of Figure 1. Then, as seen in section 3, A's crisis may have occurred because of bad fundamentals or because of unfavorable but self fulfilling market expectations. Hence the observation that a crisis happened in A provides some but not complete information about D_A. In fact, $\mu = \Pr\{D_A = D_L | crisis \text{ in } A\} = 2p_L/(1+p_L)$, which is between zero and one if $0 < p_L < 1$. Note that $\mu > p_L$: intuitively, the occurrence of a crisis in A raises the probability that A's cost of default was low. Also intuitively, μ increases in p_L: as $A's$

fundamentals become worse, the probability that a crisis in A was due to bad fundamentals also increases.

That $\mu > p_L$ makes contagion likely but is not a sufficient condition: from 5 we see that the statistical relation between A's and B's fundamentals, given by $\Pr\{D_B = D_L | D_A = D_L\}$ and $\Pr\{D_B = D_L | D_A = D_H\}$, also matters. But one can show that contagion must occur in the plausible case that $\Pr\{D_B = D_L | D_A = D_L\} > p_L > \Pr\{D_B = D_L | D_A = D_H\}$.

Note that a crisis in A can infect B even if A's crisis was caused purely by expectations and not fundamentals. This would be the case, in particular, if $D_A = D_H$, so that fundamentals turned out to be favorable, but sunspots selected the sure default outcome in A. But investors in B cannot observe the realizations of those two random variables separately. The resulting confusion then lead them to downgrade their beliefs about B's fundamentals. (A similar point is raised by Calvo 1999).

One can check that, in the setting of Figure 1, $\mu \geq p_L$ in all cases, with strict inequality unless $L_A > L^1$. So, intuitively, observing a crisis in A must raise the posterior probability that fundamentals in A were weak. Then, if there is a positive link between A's and B's fundamentals, the likelihood of weak fundamentals in B must also increase, and there will be contagion from A to B.

Case ii: In case i, the only information available in period 2 about $A's$ events was whether A had a crisis or not. What if more information is available, and sufficient information is released by a crisis to ascertain whether it was caused by fundamentals or by beliefs? In our model, investors would have enough information if they could observe the price at which government A rolled over its debt. This is because the price of the new debt is different in different equilibrium continuations.

To analyze this case, take once more the case $L^S < L_A \leq L^1$ in Figure 1and suppose that at the beginning of period 2 it is publicly known that A had a crisis *and* that the price of A's debt was $1 - p_L$. Then investors must infer that the sunspots realization in A was favorable or, equivalently, that market expectations about A were optimistic, leading to the luck of the draw equilibrium. However, since a crisis in A occurred anyway, it must have been the case that the crisis was caused by bad fundamentals. In other words, $\Pr\{D_A = D_L | crisis \text{ in } A \text{ and } q_A = 1 - p_L\} = 1$. But then $\Pr\{D_B = D_L | crisis \text{ in } A \text{ and } q_A = 1 - p_L\} = \Pr\{D_B = D_L | D_A = D_L\}$.

Compare the last expression with 5. If $\Pr\{D_B = D_L | D_A = D_L\} > p_L >$

$\Pr\{D_B = D_L | D_A = D_H\}$, and since $\mu < 1$, not only there is contagion in case ii, but that contagion from A to B is *stronger* than in case i. This may be counter intuitive but is straightforward. If a crisis was observed and the price of the debt was $1 - p_L$, it is revealed *for sure* that fundamentals in A turned out to be adverse. Hence investors update their beliefs about B's fundamentals more strongly than if they had been unable to tell if A's crisis was caused by fundamentals or beliefs.

In contrast, suppose that a crisis was observed in A, but also that $q_A = 0$. Then the appropriate inference is that A settled on a sure default equilibrium. Since in that equilibrium the crisis had to occur regardless of the realization of D_A, there is no new information that can be learned about D_A and, consequently, about D_B. It follows that $\Pr\{D_B = D_L | crisis \text{ in } A \text{ and } q_A = 0\} = \Pr\{D_B = D_L\} = p_L$. In other words, a crisis known to be driven purely by beliefs is not informative and is *not* contagious in this model. This occurs because extrinsic uncertainty is independent across countries.

5 Final Observations

Our results are of particular interest for the current debate on the role of *transparency* in the generation of crises. In our model, the scenario in which investors observe q_A in addition to whether A had a crisis is "more transparent" than the scenario in which q_A is not observed. In this sense, we have seen that more transparency does *not* eliminate contagion. Rather, it changes the way contagion takes place, making some kinds of crises are more contagious than others. In particular, more transparency exacerbates contagion from A to B, when A suffers from a *fundamentals* driven crisis. On the other hand, it makes *beliefs driven* crises less contagious. Economic reforms that arguably result in more transparency, such as dollarization, need to be reevaluated in light of this result.

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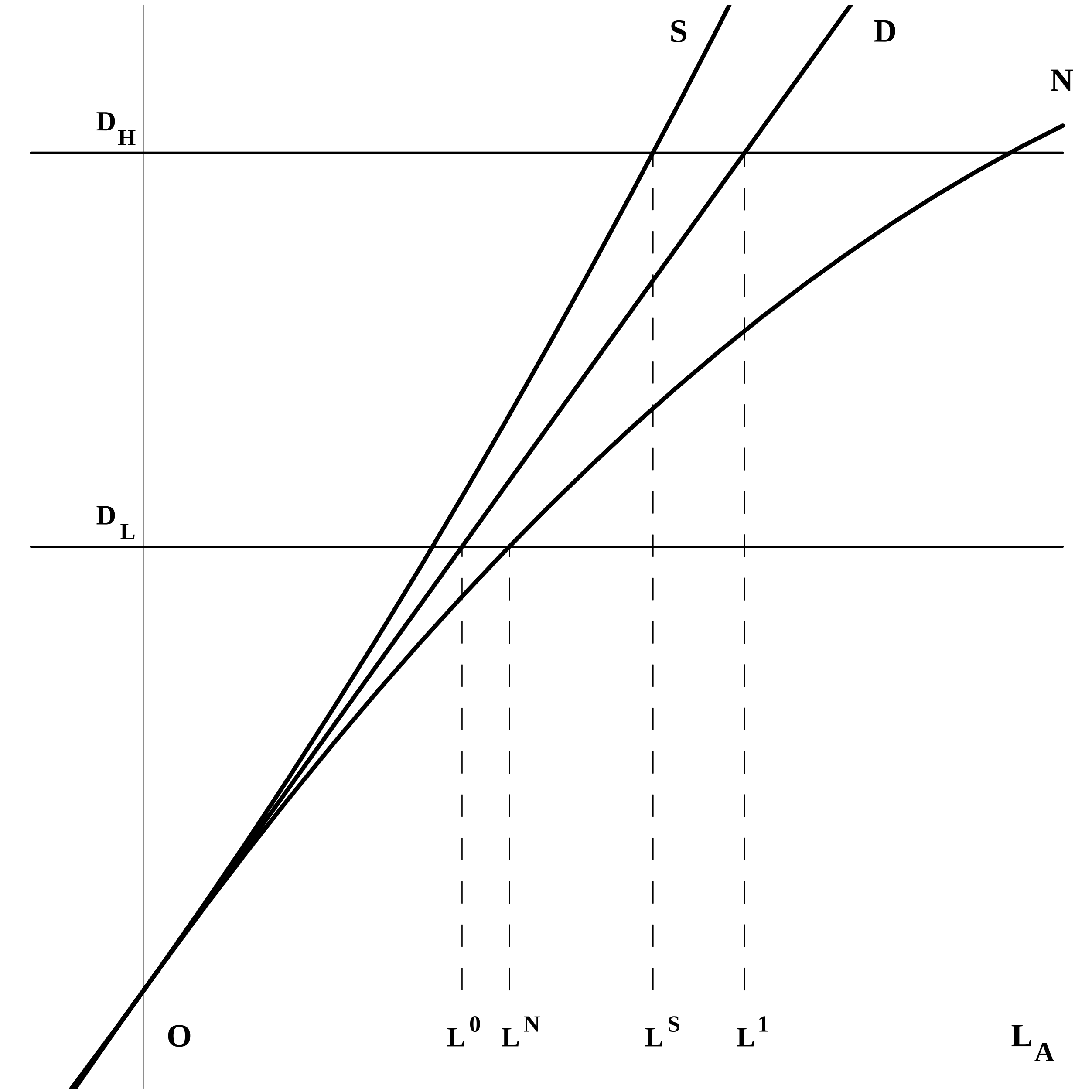
Figure 1 is given in next page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