Fundamentals, Expectations and Spread of Banking Crises

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Abstract

This paper features pure contagion of financial crises across countries, in a model where bank panics are equilibrium outcomes as a result of an asset-liability maturity mismatch. Banks' short-term liabilities include loans granted by foreign investors who have imperfect information about liquidation costs of assets. A bank failure in a country induces lenders to downgrade early-liquidation yields in other countries, and thus to bid lower prices to buy new debt. Banks become more illiquid and are therefore more prone to self-fulfilling depositors' runs. The severity of contagion sharpens with a higher degree of correlation between yields across countries and a greater strength of the Bayesian reassessment of the early-liquidation yield in the catalyst country.

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1. **Introduction**

The severity of the Asian flu and the Russian virus in 1997-98 has renewed the interest for the study of contagion and entails a deeper understanding of how a crisis might internationally spread. Close trade or financial links within regions or common external economic factors are channels of “real contagion”. Important as these conduits generally are, Masson (1999) and others have argued that these linkages were weak in the contagion of the Tequila crisis from Mexico to Argentina and Brazil in 1994-95, the contemporaneous crises in several East-Asian countries in 1997-98, and the ripple effects of the Russian default in August 1998 on many emerging markets. This makes the case for “pure contagion”, that is, the spread of crises unrelated to effective shifts in macroeconomic fundamentals.

Most models of pure contagion display an information channel. In an incomplete information environment, a crisis in one country may lead to “shifts in market sentiment”, or may lead to changes in the interpretation given to existing information. Change in the risk tolerance of investors (Kumar and Persaud, 2002) or loss of confidence underlie the former. Information reassessment can materialize in various forms: herd behavior – on the grounds of asymmetric costly information and / or size heterogeneity; or informational cascades – based on the combination of asymmetric information and sequential decisions; or a reappraisal of economic fundamentals; or an alteration in the device that enables players to coordinate on a particular equilibrium when several arise. Incidentally, this last form could illustrate a shift in market sentiment as well. The “wake-up call” hypothesis of Goldstein (1998) also is ambivalent. It means that a financial crisis in a country, possibly interpreted as an indicator of equally severe problems in others that are perceived as being in a similar macroeconomic position, may lead to a reassessment of the desirability of investing in those countries. This is why we stopped short of strongly contrasting shifts in market sentiment and reinterpretation of existing information.

Most existing models of informational contagion feature financial markets and are based on asymmetric information. Calvo (1999) presents a model of capital markets populated by informed and uninformed investors. The uninformed try to extract information from informed investors' trades. This opens up the possibility that, if informed investors are forced to sell emerging market securities, say, to meet margin calls, then uninformed investors may misread this action as signaling low returns in emerging markets. Kodres and Pritsker (2002) emphasize optimal portfolio rebalancing as a channel. When portfolio reallocation occurs in markets with information asymmetries, the resulting price movements are exaggerated because the order flow is misconstrued as being information-based.

At this point, we have made the case for informational contagion and referred to such models in which financial assets play a key role. Nevertheless, recent episodes of financial fragility went far beyond mere falls of securities prices, and therefore, it is of interest to build a model of informational contagion in line with the new theoretical foundations of crises.

The literature on financial crises has trended in new directions in the aftermath of the crises in East and Southeast Asia of 1997-98. These crises have led to a questioning of anterior models that basically viewed crises as retribution for governments that have mismanaged the economy, or as the consequences of lack of credibility. Most of the economies at stake, as a matter of fact, enjoyed government surpluses and increasing foreign exchange reserves, in contrast with the suggestions of first-generation models (Krugman (1979), Flood and Garber (1984)), and also enjoyed low unemployment and booming exports, unlike what second-generation models (Obstfeld, 1994) would imply. Accordingly, a third generation of models of financial crises has emerged, whose common denominator is the key role assigned to financial structure fragility and financial institutions. Two strings of this literature, displaying multiple equilibria, can be affiliated with Krugman (1999), Caballero and Krishnamurthy (2001) and Aghion, Bacchetta and Banerjee (2001, 2003), on the one hand, and Chang and Velasco (2000, 2001), on the other hand. The former line of works develops the so-called balance sheet approach, that is, credit-constrained firms with a high proportion of debt denominated in foreign currency, while the latter highlights bank runs concomitant to stops of capital inflows due to an internationally illiquid banking sector. Our starting point will be the framework of Chang and Velasco (2001).

While recent literature has provided theoretical foundations for either contagion or self-fulfilling crises, models in which both co-exist have barely been studied. For instance, Masson (1999) sketches the possibility of informational contagion in a second-generation model of balance-of-payments crisis, yet he stops short of specifying how a crisis in a given country entails shifts in expectations that may ignite a crisis in another country. Indeed, the key sticking point in attempting to display pure contagion in models of financial crises with multiple equilibria is that mechanisms for jumps between those equilibria are usually not articulated. Therefore, those models cannot capture a contagious effect in which a crisis in one country (i.e., a particular outcome among multiple equilibrium outcomes) affects the likelihood of a crisis in another one. It is not a catch 22 though.

A first way out is to make the most of the equilibrium selection technique pioneered by Carlsson and van Damme (1993), and implemented by Morris and Shin (1998) in a framework of speculative attacks, which makes it possible to rule out multiple equilibria, self-fulfilling prophecies notwithstanding, and relate aggregate outcomes to observable variables. A key feature of the "global games" paradigm is incomplete information about relevant economic variables. Such a vintage point generates a failure of common knowledge of the fundamentals, and therefore agents' beliefs and actions cannot be perfectly coordinated. In other words, the implicit assumption of most models with multiple equilibria no longer holds. For instance, Dasgupta (2003) studies the spread of panics between banks related by capital connections. Goldstein and Pauzner (2003) examine contagion of reversals of investment portfolios as a consequence of wealth effects for investors. Vaugirard (2004) substantiates the propagation of capital flow reversals based on changes in the interpretation given to existing information.

A second approach is to keep working with multiple equilibria while being capable of identifying a particular channel amidst the various possible aforementioned. We follow along this second line and we now specify the problem position. We mean to single out reassessment of fundamentals as a vector of informational contagion of crises. This broadly boils down to featuring a Bayesian update of economic variables, while ruling out twists in coordination of beliefs. Highlighting the former entails that we be able to determine probability of crises and to relate this probability to the distribution of fundamentals, in a context of multiple equilibria. Hence, crises must stem from the combination of realized values of economic variables and self-fulfilling expectations, as opposed to expectational shifts alone. In turn, this combination is the outcome of strategic interactions between players. We must therefore structure a strategic game sufficiently elaborated, so that players face non-trivial strategic decisions, and at the same time, amenable enough to allow for computation of probabilities. This is our challenge.

To have a clear-cut picture of how our paper contrasts with the existing literature on contagious bank failures, the reader must keep in mind two points. First, we mean to highlight international transmission of bank runs through an informational conduit. Second, these bank failures must be concomitant to sudden reversals of international capital flows and / or to falls in asset prices. Indeed, we are interested in providing theoretical foundations for the propagation of recent turmoil in the emerging markets for which these facets of financial fragility have been simultaneously observed. In this respect, merely exhibiting theoretical mechanisms for cross-country correlated banking crises misses the point; international clustering of bank failures must be displayed along with other types of financial fragility.

That being said, diverse models of contagious bank failures written so far, while not explicitly meant for multi-economy issues, could straightforwardly be adapted to international spreads by merely thinking of the corresponding banks as being located in different countries. In so doing, however, one would simply derive bank runs that are correlated across countries, which is insufficient as stated above. Yet, one such work is worth mentioning here, since we will refer to it in the body of the paper. Chen (1999) displays contagion through an informational channel. He introduces asymmetric information regarding the value of bank assets among depositors in the model of Diamond and Dybvig (1983). Therefore, a first-come-first-served rule in bank withdrawals creates information externalities forcing depositors to respond prematurely to noisy information such as failures of other banks. This paves the way for the information-cascades story we previously underscored as a possible explanation for contagion. However, bank creditors – other than depositors – being irrelevant in Chen, a multi-country interpretation of his model does not yield an additional type of fragility.

On the other hand, Garber and Grilli (1989) do exhibit contagious bank runs along with falls in asset prices. Yet, the spread takes place through financial links. Upon the materialization of a bank run in a country, a foreign banking system buys its assets, say, long-term securities, at a bargain price, thus creating a wealth effect for the representative agent of the foreign country. It follows that foreign consumers may decide to consume beyond initially expected. Since foreign banks lack sufficient liquidity to meet the implied withdrawals, the apparently favorable opportunity available to the foreign country may actually turn out to lead to a run on the foreign banking system. Nevertheless, this model featuring no foreign creditors cannot account for sudden reversals of short-term international capital flows, and therefore does not lie in the category of third-generation crisis models.

A paper related to ours is in fact a model of informational contagion of sovereign debt default, not of bank runs. Chang and Majnoni (2002) study contagion in a model in which financial crises occur due to the combination of weak fundamentals and adverse self-fulfilling expectations of international investors. A debt default in one country, while possibly triggered by purely expectational shifts, may infect other countries, as it leads investors to rationally update their beliefs about fundamentals of the latter, and therefore, to require a higher return for allowing those governments to rollover their outstanding debt; which consequently raises the likelihood of a strategic default. Thus, their model and ours have in common a Bayesian update of beliefs regarding suitable variables as the vector of contagion. That said, our paper features bank debt rollover while theirs is about public debt service. Consequently, equilibrium outcomes in their model stem from the interaction of a government strategic decision of default and foreign lenders' expectations regarding being repaid. In contrast, our model includes no such strategic decision of default, since banks possibly fail because of purely expectational depositors runs. What may appear innocuous actually entails our being much more careful when defining and deriving equilibrium outcomes.

To the best of our knowledge, no papers feature informational contagion in a third-generation model of financial crises, and this contribution is intended to fill part of this gap. In our paper, self-fulfilling domestic depositors' runs are equilibrium outcomes because of a maturity mismatch between banks' liabilities and assets. Those liabilities include loans granted by foreign creditors who have imperfect information about early-liquidation yields of illiquid assets. After observing a crisis in a country, lenders downgrade those yields in other countries, and therefore bid lower prices to buy new debt issued by their banks. As a result, those banks become more illiquid and are therefore more prone to runs. The vulnerability to contagion and its intensity sharpen with a higher degree of correlation between yields across countries and with a greater strength of the Bayesian reassessment of the early-liquidation yield in the catalyst country.

The paper proceeds as follows. In Section 2, we capitalize on the third-generation model of financial crises of Chang and Velasco (2001), that is, an open-economy extension of the bank run model of Diamond and Dybvig (1983). Yet, our respective focuses of attention are set in different directions. While they are interested in proving that banks may rationally choose to put themselves in a position of illiquidity, thus running the risk of self-fulfilling runs, we mean to highlight how foreign creditors' expectations regarding being repaid are affected by, and in turn, impinge on the likelihood of home depositors' runs. As a result, we concentrate on a stage of debt rollover, and thus take a demand deposit system as given. Importantly, we also introduce an informational edge of home depositors over foreign creditors regarding liquidation costs of assets, which is a credible story in most emerging markets. In this respect, we model the early-liquidation yield of the illiquid technology as a Bernouilli random variable.

In Section 3, we first show that bank runs stem from the combination of the realized value of the premature-liquidation yield, which conditions the liquidity position of the representative bank, self-fulfilling domestic depositors' adverse expectations and self-validating foreign creditors' beliefs regarding being repaid. Second, we prove that multiple equilibria can arise and, if so, we introduce a sunspots variable to coordinate creditors' expectations. Finally, we compute the probability of bank runs. The important conclusion of this section is that the odds of depositors' runs increase with the subjective appraisal by creditors of the chance that the short-term yield takes its low value.

In Section 4, we prove that bank runs in a country may propagate to another country via an informational channel, as foreign creditors reassess early-liquidation yields. The rationale underlying this international transmission can be disentangled as follows. First, the materialization of a bank run in a country induces international lenders to downgrade the early-liquidation yield of the illiquid technology in that country.

Indeed, since the likelihood of bank runs is increasing in the prior probability of the early-liquidation yield taking its low value, then, upon occurrence of a run, the posterior probability that the yield takes its low value rises, on the grounds of Bayes' rule. Second, that downgrade in the catalyst country in turn implies a downgrade in the other country, provided their short-term yields are positively correlated. And third, that reappraisal in the other country consequently entails bank runs being more likely in that country, using again the important result of the previous section.

Section 5 emphasizes that both the degree of correlation between yields across countries and the strength of the Bayesian reassessment of the early-liquidation yield in the catalyst country play a crucial role in the vulnerability to contagion as well as its intensity.

Section 6 summarizes the central findings, and discusses some suggestions for future research.

2. Model

In this section, banks are described as maturity transformers that take liquid deposits and borrow foreign funds, and invest part of the proceeds in illiquid assets. This results in a maturity mismatch between their liabilities and their assets, therefore creating the possibility of self-fulfilling bank runs.

Our starting point is an open-economy extension by Chang and Velasco (2001) of the bank run model of Diamond and Dybvig (1983). We will however depart from Chang and Velasco's model, hereafter referred to as the "benchmark model", in several ways. First and more importantly, our respective focuses of attention are set in different directions. While they are interested in proving that banks may rationally choose to put themselves in a position of illiquidity, therefore running the risk of self-fulfilling runs, we mean to shed light on how foreign creditors' expectations regarding being repaid are affected by, and in turn, impinge on the likelihood of home depositors' runs. As a result, while they must first derive optimal (complete) allocations, we concentrate on a stage of debt rollover by the bank, and thus take an allocation as given, merely imposing that some compatibility conditions be satisfied. Second, and consistently with our different focus of attention, whereas our framework features foreign creditors' rational-expectations decision regarding what price to charge for allowing the bank to rollover its outstanding debt, the benchmark model merely considers either mechanical full rollover or no rollover at all. Consequently, our model captures a strategic interaction between domestic depositors, on the one hand, and foreign creditors, on the other hand, while the benchmark model merely displays a coordination game among depositors. In this respect, we take a stance close to a variant of the benchmark model by Chang and Velasco (2000). Third, we introduce an informational edge of home depositors over foreign creditors regarding liquidation costs of assets. That information asymmetry, along with the strategic interplay, enables us to obtain an extensive set of equilibria in the resulting game, which may yield multiple equilibria, eventually. And then, we will extend the model to a two-economy framework, in the section of contagion.

2.1. Setup

In this subsection, we lay down the main traits of the benchmark model. As in Diamond and Dybvig (1983), a combination of preferences and investment technologies is such that depositors are better off by forming a "bank" rather than acting in isolation.

A small open economy is populated by a large number of ex ante identical agents. There are three periods indexed by $t = 0, 1, 2$, and only one good, which is freely traded in the world market and can be consumed and invested. The price of consumption in the world market is fixed and normalized at one unit of foreign currency (a "dollar"). Home agents can borrow only from identical foreign lenders. These creditors are assumed risk-neutral – which is consistent with the small size of the economy, and can freely borrow or lend in a world capital market where interest rates are zero. Hence, foreign creditors will lend to domestic agents if and only if they are (credibly) promised an expected net return of zero. Also, domestic agents can invest as much as they want in this world capital market.

The country enjoys access to a long-term technology whose yield per dollar invested at $t = 0$ is $R > 1$ dollars at $t = 2$, and $r < 1$ dollars at $t = 1$. In other words, an investment is productive if held for two periods, but illiquid. While there is no uncertainty about R, r is a random variable whose distribution as well as the corresponding information structure will be made precise in the next subsection.

Each domestic agent may be forced to consume early depending on her "type", which she discovers at $t =$ 1. With probability λ she is "impatient" and derives utility only from Period-1 consumption, while with probability $(1 - \lambda)$ she is "patient" and derives utility only from Period-2 consumption. Type realizations are independently and identically distributed (i.i.d.) across agents. In addition, the realization of each agent's type is private information to that agent. Incidentally, the long-term yield R and the proportion λ of impatient consumers being assumed constant, there is no aggregate uncertainty in this model, unlike Allen and Gale (1998)'s.

In this setup, it can be proved that risk-averse domestic agents may profit from pooling their resources and acting collectively rather than in isolation. Accordingly, it is assumed that they form a coalition, called a "bank". Indeed, this bank perfectly forecasts its liquidity needs at Period 1, as a result of the law of large numbers, and thus will not plan to liquidate prematurely part of the long-term asset, since this is costly. On the other hand, individuals cannot accurately forecast their liquidity needs, since they do not know their type until Period 1, and may therefore plan to liquidate their long-term assets early, thus costly, if they turn out to be impatient. To reinforce this incentive to act collectively, we could possibly argue that a coalition has a comparative advantage in investing in projects due to size indivisibilities.

2.2. Debt rollover and information structure

In this subsection, we focus on the step of debt rollover by the bank, and we depart from the benchmark model in that we introduce asymmetric information between depositors and creditors regarding the early-liquidation yield of the illiquid asset.

The representative bank designs demand deposits. These contracts stipulate that, in Period 0, each agent must surrender to the bank her endowment and her capacity to borrow abroad, in return for the right to withdraw, at her discretion, either x units of consumption in Period 1 or y in Period 2. The bank borrows abroad an amount f in Period 0, with a part d of this debt maturing in Period 1, referred to as the short-term debt hereafter, and thus $f - d$ maturing in Period 2. The bank uses the proceeds of its borrowing, f, along with the endowment surrendered by home agents, e, to invest an amount k in the long-term illiquid technology and to invest an amount b in the world capital market. This means that the bank buys b dollars of the world liquid asset as international reserves.

At this point, we take an allocation as given, as elaborated upon introducing this section. Chang and Velasco (2000, 2001) derive optimal complete allocations and prove that banks may be prone to crises. They may rationally choose to put themselves in a position of illiquidity, thus taking the risk of self-fulfilling runs, if the cost of doing so is more than offset by the expected payoff of the long-term technology. In contrast, we mean to highlight how creditors' expectations regarding being repaid are affected by, and in turn condition the likelihood of depositors runs. Therefore, acknowledging that it has already been vindicated that deposit contracts may comprise run equilibrium outcomes, we take an allocation as given, merely imposing that some compatibility conditions be satisfied. Incidentally, Garber and Grilli (1989) and Chen (1999) take a similar stance. Besides, our focus being the step of the bank's debt rollover, we must set d exogenously, as contrasted with an amount of ongoing debt previously determined within an optimal allocation. In the same vein, we want to keep room to maneuver for x and d so as to later exhibit several types of equilibrium. In addition, from a practical standpoint, it is dubious that demand deposit systems are determined with optimizing programs, solvency ratios notwithstanding. Not only do new management teams inherit situations, in all countries, but also, and particularly in emerging markets, such contracts more likely stem from domestic political conditions or the amount of funds available in international markets, not to mention the extent of crony capitalism.

We now concentrate on Period 1, with the short-term debt maturing. The representative bank attempts to roll it over by selling to foreign creditors claims to d dollars, payable in Period 2, in a competitive auction. These foreign creditors have an opportunity cost of funds of zero within Periods 1 and 2, and thus, being rational and risk-neutral, will buy the new debt issue if and only if its price, denoted by S, is equal to their subjective probability that the debt will be honored. The auction proceeds, $X = Sd$, are immediately transferred to the bank, which simultaneously pays out its maturing debt amounting to d. Hence, the net outflow attached to the debt operation in Period 1 is $(1 - S)\, d$.

ASSUMPTION 1: Domestic depositors have an informational edge over foreign creditors regarding early-liquidation yields. More precisely, the true value of r becomes known to home agents at Period 1, upon deciding on whether or not to run on the bank. On the other hand, foreign lenders only know its prior distribution, when about to make the decision regarding buying the new debt issue. For the sake of simplicity, we assume that this distribution is a Bernouilli random variable, taking a low value r_L, with probability $q \in\ ]0, 1[$, or a high value r_H, with probability $(1 - q)$, which satisfy $r_L < r_H < 1$.

This informational edge is a credible story in emerging markets. Liquidation costs depend on each country's strength of bankruptcy laws as well as their enforcement, which implies that home depositors have a clear informational advantage, since information acquisition is costly for foreign lenders. This bias is further increased if we account for the fact that domestic agents may even take actions that affect these costs and for the opacity that surrounds cronyism. Foreigners are therefore unlikely to truly know the liquidation values until there actually is a run. By the same token, early-liquidation yields are likely to be correlated across emerging markets. We will return to that last point in the section on contagion.

ASSUMPTION 2: The withdrawal limits x and y of the deposit contract satisfy the conditions:

$$\lambda x \leq b, \tag{1}$$

$$(1 - \lambda)y + f \leq Rk, \tag{2}$$

and

$$x \leq y. \tag{3}$$

Condition (1) is a Period-1 feasibility constraint stating that the values of x and b chosen by the bank must be such that its Period-1 liquidities cover the expected withdrawals for consumption of the impatient. It is meant to ensure that an equilibrium without runs always exists. This inequality yet warrants two comments. First, the bank implicitly acknowledges that it will not liquidate prematurely the illiquid asset. Second, the bank implicitly expects the outstanding short-term debt d to be fully rolled over. This means that the bank disregards the possibility of depositors' runs when setting the value of x. Nonetheless, the probability of bank runs is strictly positive in the models of Chang and Velasco (2000, 2001) as pointed out above, which implies that stating Condition (1) in that form entails assuming away rational expectations for the bank, i.e., at a collective level. In other words, we assume that the exogenous event (sunspot) that could trigger a bank run in Period 1 is completely unexpected as of Period 0, which rules out, strictly speaking, rational expectations. In so doing, we follow along the lines of Garber and Grilli (1989) and Chang and Velasco (2001). It is noteworthy that Chang and Velasco (2000) relate deriving a continuum of optimal allocations (vs. unique solution) to disregarding the possibility of bank runs. This is fully consistent with our model that intends to keep some margin in setting x and d, as already pointed out. What is more, we will later constrain the probability of adverse sunspots to be low, which further improves the suitability of our framework.

Condition (2) is a Period-2 feasibility constraint. In particular, it ensures that foreign creditors are fully reimbursed the amount extended in Period 1, provided the bank does not go bankrupt in the meantime.

Condition (3) is an incentive-compatibility constraint relative to patient agents. If a patient depositor claims impatience, she obtains x in Period 1. The best she can do is then to deposit that amount in the world market, and hence get back and consume x in Period 2. On the other hand, by not misrepresenting her type, she is entitled to withdraw y in Period 2. Condition (3) is thus a truth-telling incentive that the bank must respect since agents' types are private information to them. However, whether or not patient agents will behave accordingly will depend on their expectations about being in fact served in Period 2, to which we turn next.

3. Equilibria

In this section, we first show that bank runs stem from the combination of the realized value of the early-liquidation yield, which conditions the liquidity position of the representative bank, self-fulfilling domestic depositors' adverse expectations, and self-validating foreign creditors' beliefs regarding being repaid. Second, we prove that multiple equilibria can arise and, if so, we introduce a sunspots variable to coordinate creditors' expectations. Finally, we compute the probability of bank runs and highlight that their likelihood increases with the subjective appraisal by creditors of the chance that the short-term yield takes a low value. In our model, informational contagion of crises is rooted in that last result.

We refer to the introduction of Section 2 for a perspective on how our modifications of the benchmark model allow to reach an extensive set of equilibria. What is more, while these amendments may appear innocuous, they actually entail that we be careful about specifying equilibrium outcomes.

3.1. Timing

In this subsection, we expound the timing of withdrawals and debt rollover in order to properly define depositors' and creditors' decision problems.

Domestic depositors learn their type in Period 1, and face the strategic decision on whether or not to withdraw according to their true type. Simultaneously, foreign creditors must decide what price to bid for the new debt issued by the bank, and this, according to their prior assessment of the early-liquidation yield. To make these decision problems well defined, we make an additional assumption on the demand deposit system. The bank attends to the requests of depositors on a first-come-first-served basis. This assumption is essential in that it provides late consumers an incentive to misrepresent their type if they fear a bank failure, which paves the way for bank runs. On the other hand, if late consumers behave according to their true type, the bank will not fail according to Condition (1), and they will be better off due to Condition (3). It follows that depositors face indeed a non-trivial strategic decision.

Hence, depositors visit the bank in random order at Period 1. Upon their respective arrival to the bank, each depositor may withdraw x on demand. To service withdrawals and short-term debt repayment, the bank first uses its world liquid asset b and attempts to roll over its maturing debt d, and then liquidates part of the long-term asset if necessary. Besides, the auction among creditors concerning the debt rollover was described in the previous section.

3.2. Definitions

This subsection is devoted to properly defining equilibrium outcomes and to highlighting that international lenders' beliefs – regarding the chance of being repaid if they enable the bank to extend its short-term debt – interact with home depositors' self-fulfilling expectations, to magnify the odds of depositors runs, eventually.

An equilibrium is a description of the strategies of depositors and creditors and of aggregate outcomes such that: the aggregate outcomes are implied by those strategies; and each depositor or creditor strategy is optimal for her, given the aggregate outcomes. We stress that the strategic game in which those actors are involved can further be disentangled into two sub-games. The first one is a strategic interaction between the group of home depositors, on the one hand, and the group of foreign creditors, on the other hand. The second one is a coordination game among domestic depositors upon deciding whether or not to run. Moreover, foreign lenders would have to coordinate their behavior so as to select an equilibrium should several arise.

Let us first note that the game has an "honest equilibrium" in which each depositor withdrawal decision matches her true type and creditors allow for the full rollover of the short-term debt. This stems from the bank's solvency conditions and the incentive compatibility clause stated in Assumption 2. Hence, we concentrate on equilibria comprising bank run outcomes.

DEFINITION 1: The bank is illiquid if its potential short-term liabilities exceed the liquidation value of its assets. Formally:

$$x + (1 - S)\, d > rk + b, \tag{4}$$

where r is the realized value of the early-liquidation yield. We remind that S is the price bid by lenders for the new debt issue, and that it is equal to their subjective probability that the debt will be honored.

Incidentally, we use in (4), "r" for an *ex post* value, as for the random variable. This is meant to keep notation at a minimum, and hopefully not misleading, since we will use r_H or r_L in the sequel.

Now, a bank run equilibrium exists if and only if the bank is illiquid. Indeed, suppose Condition (4) is satisfied. If all depositors attempt to withdraw their deposits in Period 1, this collective behavior turns out to be individually optimal since it forces the bank to fail before meeting all the claims made on it. The converse holds true due to the truth-telling condition (3): If (4) is not satisfied, then depositors cannot force the bank to go bankrupt; therefore, patient consumers who run get x instead of $y \geq x$, which means that running is not individually optimal.

ASSUMPTION 3: Depositors base their decision to run on the realization of sunspots and the bank's liquidity position. More specifically, there is a publicly-observed random variable that takes the value 1 with probability $p \in [0, 1]$ or 0 with probability $1 - p$. While this variable does not affect the fundamentals of the economy, depositors condition their behavior on its realization, that is, it acts as a coordination device: A bank run takes place if and only if the bank is illiquid and the realization of the sunspot variable is 1.

We first emphasize the depositors' decision process, and then point out several implications of this assumption. Home depositors base their decision on whether or not to run on two cumulative factors. First, they assess the liquidity position of the representative bank. Second, conditionally on the bank being illiquid, they coordinate their expectations, thus their behavior, by means of a mechanism, extraneous to economic fundamentals. Yet, it is noteworthy that the former actually involves a third factor: the appraisal by depositors of the return required by foreign creditors to enable the bank to roll over its outstanding debt. This assessment in turn entails that domestic depositors have to account for the fact that liquidation costs of the long-term asset are uncertain to foreign agents. In other words, though knowing the true values of those costs upon making a decision regarding early withdrawal, late consumers must take account of their randomness to foreigners.

Assumption 3 warrants further comments. First, Condition (4) being satisfied, both runs and no-runs are possible equilibrium outcomes. Otherwise saying, a run is never a sure outcome. Second, foreign creditors' behavior conditions the likelihood of runs, in the sense that Condition (4) is more stringent than its counterpart with full rollover (i.e., $S = 1$). Actually, the behavior of creditors may, by itself, cause a depositors' run: It may be the case that (4) holds with $S < 1$ and does not hold with $S = 1$. Third, if there is a run, creditors who would have accepted to buy the new debt, would be repaid nothing in Period 2, since the bank goes bankrupt. Points 2 and 3 taken together imply that, not only is it rational for creditors not to enable the bank to rollover its debt if they fear a depositors' run, but also, this fear may be self-fulfilling. Fourth, lenders are repaid if and only if there are no runs. Indeed, they are fully reimbursed if depositors do not run, as ensured by Condition (2) (the bank then does not fail in Period 1 by virtue of Provision (1), and thus, Condition (2) applies), while they are paid nothing back if depositors run in Period 1 (Point 3 above). It follows that rational risk-neutral foreign creditors, who bid the price of the new debt to the probability of being paid back, offer $S = 1 - g$, where g is the ex ante probability of bank runs.

We are now equipped to determine equilibrium outcomes.

3.3. Equilibrium types and multiple equilibria

For clarity, we label as an "equilibrium type", an equilibrium defined in association with the early-liquidation yield. We first display equilibrium types that can arise according to the parameters of the demand deposit system, and then prove that two types of equilibrium can simultaneously arise.

Equilibria can be of three types depending on the deposit contract set by the bank. First, a run equilibrium is a possible outcome irrespectively of the realization of r. This means that Condition (4) holds for r_H (*a fortiori* for r_L). Therefore, the probability of a run is p (probability of adverse sunspot for depositors). International creditors acknowledge this, and accordingly bid $S = (1 - p)$ (see Point 4 in comments of Assumption 3), which amounts to a debt rollover of pd. This means that a necessary and sufficient condition (NSC) for there be a run equilibrium irrespectively of the realization of r is:

$$x > x_S = r_H k + b - pd. \tag{5}$$

Second, a run equilibrium is a possible outcome if and only if the early-liquidation yield takes its low value. This means that Condition (4) holds for r_L and does not hold for r_H. It follows that the probability of a run is pq – where q is the probability of r being equal to r_L – and that creditors bid $S = (1 - pq)$, which boils down to a debt extension of pqd. As a result, a NSC for there be a run equilibrium only if $r = r_L$ is:

$$x_1 = r_H k + b - pqd > x > x_0 = r_L k + b - pqd\ . \tag{6}$$

Third and last, a run equilibrium is not a possible outcome irrespectively of the realization of r. This means that Condition (4) never holds. The probability of a run being zero, rational creditors bid $S = 1$, that is, there is full rollover of the debt. Consequently, a NSC for this type of equilibrium is:

$$x < x_N = r_L k + b. \tag{7}$$

Now, there are several possibilities for the respective positions of x_0, x_1, x_N, and x_S. The only inequalities that hold are: $x_0 < x_1$, $x_S < x_1$, and $x_0 < x_N$; and taking account of all cases would be tedious. Fortunately, it turns out that there is only one remaining case: $x_0 < x_N < x_S < x_1$, if restricting the analysis to low values of p. Indeed, it suffices to observe that, for $p = 0$, $x_S = r_H k + b$, thus, is superior to x_N; and therefore, it follows by continuity that this inequality still holds for p low enough. Then, we make use of the previous three inequalities to obtain the only remaining possibility. We assume in the sequel that p is sufficiently low so as to be in this case. Incidentally, we refer to our discussion following Assumption 2 regarding the suitability of restricting to a low p.

At this point, we have showed that there are three types of equilibrium, and we now claim that two types can simultaneously stand. In other words, there may be multiple equilibria. More specifically, only one type of equilibrium can arise in the three following situations for the withdrawal limit: $x < x_0$ (run equilibrium outcome never possible), $x > x_1$ (run always possible), and $x \in\ ]x_N, x_S[$ (run possible if and only if $r = r_L$). On the other hand, two types of equilibrium coexist in the two following situations: $x \in\ ]x_0, x_N[$ (both outcomes "never run" and "run if and only if $r = r_L$" can arise), and $x \in\ ]x_S, x_1[$ (both outcomes "run always possible" and "run possible if and only if $r = r_L$" are possible). Incidentally, we previously underscored that the representative bank is prone to runs, which means that the situation $x < x_0$ can be assumed away without loss of generality.

3.4. Equilibrium selection and probability of bank runs

In this subsection, we first introduce sunspots specific to creditors, and then compute the ex ante probability of bank runs. This eventually enables us to emphasize that this probability increases with the chance that the early-liquidation yield takes a low value, which opens the door for informational contagion.

We saw that x can be such that two types of equilibrium arise. If so, we need a mechanism to coordinate foreign creditors' expectations. We assume that there is an equiprobable random variable that allows them to select a particular equilibrium. This sunspots variable has no effects on economic fundamentals and is independent of that one defined for domestic depositors. We take weights of ½ for the sake of simplicity.

Once this coordination device is specified, the model determines the ex ante probability of bank run equilibrium outcomes. To illustrate, suppose that x lie in $]x_S, x_1[$. With probability ½, the equilibrium type is “run equilibrium outcome possible irrespectively of realization of r”, and then, the probability of a run equilibrium outcome is p; and with probability ½, the equilibrium type is “run equilibrium outcome possible if and only if $r = r_L$”, and then, the probability of a run is pq. It follows that the probability of a bank run is ½ $p(1 + q)$, in the case $x \in \left]x_S, x_1\right[$. Likewise, the probability of a bank run in the case $x \in \left]x_0, x_N\right[$ is ½ pq. Also, in the case $x > x_1$ ($x \in \left]x_N , x_S\right[$, respectively), the probability of a bank run is p (pq, respectively).

In a nutshell, there are four configurations. Two of them display one equilibrium type; a run equilibrium outcome exists in either configuration, yet conditionally on the realization of r; and then, whether or not a run does materialize depends on sunspots for home depositors. Two other configurations feature two types of equilibrium each; in either configuration, the selection between the two equilibrium types is based on sunspots for foreign creditors; in either configuration and for either equilibrium picked, a run equilibrium outcome exists; and then, whether or not a run actually takes place depends on sunspots for home depositors.

The important conclusion of this subsection is that the probability of bank runs increases with q, the prior subjective probability that the early-liquidation yield of the illiquid asset is low. The underlying rationale is that the more likely a low yield, the lower the price bid by foreign creditors to buy the new debt issue, hence the more likely the bank in an illiquid position for any given demand deposit parameters. Actually, this holds except for the case $x > x_1$ (i.e., withdrawal limit x set high), in which the probability of a run is already the highest possible (= p), making a rise in q irrelevant.

Eventually, bank runs stem from the combination of the realized value of the early-liquidation yield, which conditions the liquidity position of the representative bank, self-fulfilling domestic depositors' adverse expectations and self-validating foreign creditors' beliefs regarding being repaid. Those creditors' beliefs are themselves linked to their assessment of the early-liquidation yield of the illiquid asset. So far, we have likened this subjective assessment to the prior distribution, and have not thought of what may affect this appraisal. A crisis in another country may have this role, as we turn to next.

4. Contagion

In this section, we prove that bank runs in a country may propagate to other countries through an informational channel, as international creditors reassess early-liquidation yields.

The rationale underlying this international transmission can be disentangled as follows. First, the materialization of a bank run in a country induces international lenders to downgrade the early-liquidation yield of the illiquid technology in that country. Indeed, the likelihood of bank runs were showed to be increasing in the prior probability of the early-liquidation yield taking its low value; therefore, upon occurrence of a run, the posterior probability that the early-liquidation yield takes its low value rises, on the grounds of Bayes' rule. Second, that downgrade in the catalyst country in turn implies a rise in the subjective probability that the early-liquidation yield takes its low value in another country, provided these yields are positively correlated across countries. And third, that rise in probability in the other country consequently entails bank runs being more likely in that country, using again the important result of the previous section.

We laid down in the introduction various possible explanations for informational contagion in the framework of multiple equilibria. We have already ruled out some of them by construction: Herd behavior, since foreign creditors have the same information and the same size; Informational cascades, since they act simultaneously; Shifts in risk aversion, since creditors are risk-neutral. In the remainder of this section, we first assume away alterations in the coordination device of expectations as a possible culprit for the spread of crises, and then, we formally prove that informational contagion arises from reappraisal of early-liquidation yields by international lenders. Along the way, we highlight that cross-country correlation of yields is necessary to ignite this engine of contagion.

4.1. Two-country model

We extend the preceding framework to two economies. We specify the distributional relation between the liquidation costs of their technologies, and we pay attention to the sequential coordination of international lenders' expectations.

We consider two small open economies, say, A and B, during two consecutive periods. Country A is the economy examined in the previous section, and we re-label its parameters with Superscript A, while using Superscript B in the other country. The two countries have the same fundamental structure. The analysis in Country B is analogous to A, except for the crucial fact that international lenders know whether or not a bank run has occurred in A when about to make a decision re buying the new debt issued by the representative bank in B. We mean to prove that a financial crisis in A may impinge on the likelihood of a run in B due to this additional information. We first lay down two important assumptions.

ASSUMPTION 4: Early-liquidation yields of illiquid assets are positively correlated across countries.

This assumption is essential to informational contagion. Groups of countries in emerging markets display clear-cut similarities relevant for liquidation values: the strength of bankruptcy laws, the extent of their enforcement, the fact that domestic agents may even take actions that affect these costs, or the opacity that surrounds crony capitalism. This homogeneity entails early-liquidation yields being correlated across these countries. Besides, together with that information acquisition is costly, not only does it also imply that home agents have an informational edge over foreign creditors regarding these early-liquidation yields, as was previously stated, but also that foreigners are likely to reappraise liquidation values should a run materialize in any of those countries.

ASSUMPTION 5: Sunspots variables concerning creditors are independently and identically distributed across time and countries. This not only means that, when multiple equilibria exist, the manner an equilibrium is selected in *B* is the same as in *A*, but also, and more importantly, that the coordination mechanism in *B* is independent of what occurred in *A*.

This assumption clears up the ambiguity underscored in the introduction. We rule out alterations in the coordination device of foreign creditors' expectations following a run in *A*. It follows that the sole remaining vector of informational contagion is here the reassessment of liquidation yields, which we formally prove next.

4.2. Informational contagion

International creditors condition their behavior at the debt auction of Country-*B*'s representative bank, not on the unconditional probabilities of *B*'s premature-liquidation yield, but on such probabilities conditional on whether there was a crisis in *A*. This opens the door for contagion.

THEOREM 1: There is informational contagion from Country *A* to Country *B*, that is to say, a bank run in Country *A* increases the likelihood of a bank run in Country *B*, and this infection is solely based on a Bayesian update of international creditors' beliefs about early-liquidation yields.

We refer to the introduction of this section for the underlying rationale.

Proof: □ We showed in the previous section that the likelihood of bank runs increases with q, the foreign creditors subjective probability of the early-liquidation yield taking its low value. It therefore suffices to prove that this subjective assessment regarding B-technology increases if a crisis materializes in Country A, to obtain the theorem. Specifically, we must check that:

$$P(r^B = r^B{}_L \mid C^A) \geq P(r^B = r^B{}_L), \tag{8}$$

where the LHS member stands for the probability of r^B being low, conditional on a crisis in Country A.

While the economic intuition behind (8) is clear-cut and was sketched after Assumption 4, formally proving it involves coping with the different configurations displayed in Section 3. This will lead to some tedious but necessary computations.

We start with the two simple configurations where only one type of equilibrium exists in Country A. One of them is $x^A > x^A{}_1$, i.e., a bank run in A is always possible, irrespectively of the realization of r^A. In this case, a crisis in A means that the sunspots variable for A-depositors takes the unfavorable value, say, $D^A = D^A{}_U$. We thus obtain:

$$\begin{aligned} P(r^B = r^B{}_L \mid C^A) &= P(r^B = r^B{}_L \mid D^A = D^A{}_U) \\ &= P(r^B = r^B{}_L), \end{aligned} \tag{9}$$

where the second equality follows from the assumption that sunspots variables do not affect economic fundamentals. Thus, in this case, (8) actually is an equality. The intuition for this was somehow sketched when commenting on the probability of bank runs in the end of the preceding section. Indeed, in the case $x^A > x^A{}_1$ (i.e., withdrawal limit x^A set high), the probability of a run in A is already the highest possible (= p), which sterilizes the effect on the likelihood of a run in A of a rise in the probability of the early-liquidation yield taking its low value. Thus, the materialization of a run in A does not change the (posterior) appraisal of the early-liquidation yield in Country A, thus in Country B either.

In the three other cases, Inequality (8) holds strictly as we now show. The other configuration with one type of equilibrium is $x^A{}_N < x^A < x^A{}_S$, i.e., a run in A is possible if and only if $r^A = r^A{}_L$. In this case, a crisis occurs in A if $r^A = r^A{}_L$ and the sunspots variable for A-depositors takes the unfavorable value, $D^A = D^A{}_U$. We thus obtain:

$$
\begin{aligned}
P(r^B = r^B{}_L \mid C^A) &= P(r^B = r^B{}_L \mid (r^A = r^A{}_L) \cap (D^A = D^A{}_U)) \\
&= P(r^B = r^B{}_L \mid r^A = r^A{}_L) \\
&> P(r^B = r^B{}_L), \qquad (10)
\end{aligned}
$$

where the second equality again follows from the assumption that sunspots variables do not affect economic fundamentals, and the strict inequality follows from the positive correlation between r^A and r^B. Thus, in this case, we have proved that Inequality (8) holds strictly.

We now consider a configuration with two types of equilibrium possible: $x^A{}_S < x^A < x^A{}_1$. The first type is "run in A is possible irrespectively of value of r^A"; the second type is "run in A is possible if and only if $r^A = r^A{}_L$". The selection between the two types is based on the sunspots variable F^A for foreign creditors, which takes two values, $F^A{}_1$ or $F^A{}_2$, each with probability ½. C^A can thus be disentangled as:

$$
C^A \equiv \{(F^A = F^A{}_1) \cap (D^A = D^A{}_U)\} \text{ū} \{(F^A = F^A{}_2) \cap (r^A = r^A{}_L) \cap (D^A = D^A{}_U)\}, \qquad (11)
$$

where the symbol ū designates the union of two disjoint sets. It follows that:

$$
\begin{aligned}
P(r^B = r^B{}_L \mid C^A) &= P(r^B = r^B{}_L \cap C^A) \,/\, P(C^A) \\
&= \{P((r^B = r^B{}_L) \cap (F^A = F^A{}_1) \cap (D^A = D^A{}_U)) \\
&\quad + P((r^B = r^B{}_L) \cap (F^A = F^A{}_2) \cap (r^A = r^A{}_L) \cap (D^A = D^A{}_U))\} \,/\, P(C^A) \\
&= \{P(r^B = r^B{}_L)\, P(F^A = F^A{}_1)\, P(D^A = D^A{}_U) \\
&\quad + P((r^B = r^B{}_L) \cap (r^A = r^A{}_L))\, P(F^A = F^A{}_2)\, P(D^A = D^A{}_U)\} \,/\, P(C^A) \\
&= \{P(r^B = r^B{}_L)\, P(F^A = F^A{}_1)\, P(D^A = D^A{}_U) \\
&\quad + P((r^B = r^B{}_L) \mid (r^A = r^A{}_L))\, P(r^A = r^A{}_L)\, P(F^A = F^A{}_2)\, P(D^A = D^A{}_U)\} \,/\, P(C^A), \qquad (12)
\end{aligned}
$$

where we use again that sunspots do not affect economic variables, together with that depositors and creditors sunspots variables are independent. Further, making use again of: $P(r^B = r^B{}_L \mid (r^A = r^A{}_L) > P(r^B = r^B{}_L)$, due to the positive correlation between r^A and r^B, (12) yields:

$$P(r^B = r^B_L \mid C^A) \; > \{P(r^B = r^B_L)\, P(F^A = F^A_1)\, P(D^A = D^A_U)$$

$$+ P(r^B = r^B_L)\, P(r^A = r^A_L)\, P(F^A = F^A_2)\, P(D^A = D^A_U)\} \,/\, P(C^A). \qquad (13)$$

Putting $P(r^B = r^B_L)$ in factor in the RHS of (13), we obtain Inequality (8), strictly.

Last, deriving (8) for the other configuration with two possible types of equilibrium: $x^A_0 < x^A < x^A_N$, is straightforward. Indeed, since C^A then boils down to $\{(F^A = F^A_1) \cap (r^A = r^A_L) \cap (D^A = D^A_U)\}$, it follows that: $P(r^B = r^B_L \mid C^A) = P(r^B = r^B_L \mid r^A = r^A_L) > P(r^B = r^B_L)$.

To sum it up, we have showed that, $P(r^B = r^B_L \mid C^A) > P(r^B = r^B_L)$, in all configurations, except for configuration "$x^A > x^A_1$", where it is an equality. This completes the proof of Theorem 1. □

We have proved that bank runs in a country may propagate to other countries, as international creditors reassess early-liquidation yields. At this point, we concede however that the use of Bayes' rule to update beliefs *within the catalyst country* is not apparent. It is actually mingled with other quantities above. To illustrate, take the configuration leading to (10). We have $C^A \equiv (r^A = r^A_L) \cap (D^A = D^A_U)$, thus, $P(r^A = r^A_L \mid C^A) = 1$. Consequently, this Bayesian update is somewhat hidden when proving (10). The next section is somehow intended to sort this out.

5. Discussion

In this section, we show that both the degree of correlation between yields across countries and the strength of the Bayesian reassessment of the early-liquidation yield in the country in which the crisis originates play a crucial role in the vulnerability to contagion as well as its intensity.

PROPOSITION 1: The intensity of contagion satisfies the relation:

$$P(r^B = r^B_L \mid C^A) - P(r^B = r^B_L) = [P(r^B = r^B_L \mid r^A = r^A_L) - P(r^B = r^B_L)]$$

$$* \, [P(r^A = r^A_L \mid C^A) - P(r^A = r^A_L)] \,/\, [1 - P(r^A = r^A_L)], \qquad (14)$$

where the LHS is our definition and measure of intensity (or size) of contagion.

We first comment on Proposition 1 before proving it. It displays how the dependence between the yields, measured by the first factor of the RHS of (14), and the extent of the beliefs update about the yield in the catalyst country, as reflected by the second factor of the RHS, combine to entail contagion down the road. We purposely do not use the word "reinforce" as will be clear right on. Formula (14) has several important implications. First, it shows that a statistical positive relation between the yields is necessary for vulnerability to contagion, in a two-country model. This can be contrasted with the findings of Goldstein and Pauzner (2003) who exhibit contagion through wealth effects, while assuming away cross-country correlation between economic fundamentals. Second, it shows that a Bayesian update of the early-liquidation yield *in the catalyst country* is also necessary to activate contagion. To put it another way, dependence between yields, while necessary, is not sufficient to make a country vulnerable to contagion. Third, the intensity of contagion increases with the extent of the Bayesian update in the catalyst country. Points 2 and 3 respond to the point raised upon concluding the previous section. Besides, after the computations made in the following proof, we will be capable of ranking configurations according to the size of contagion.

Proof of Proposition 1: □ We first prove (14) in Configuration 3, where:

$$C^A \equiv \{(F^A = F^A{}_1) \cap (D^A = D^A{}_U)\} \cup \{(F^A = F^A{}_2) \cap (r^A = r^A{}_L) \cap (D^A = D^A{}_U)\},$$

and then we will show that (14) applies in a basic fashion in other configurations.

To do so, we capitalize on Equality (12). Likewise, we have:

$$\mathrm{P}(r^A = r^A{}_L \mid C^A) = \{\mathrm{P}(r^A = r^A{}_L)\, \mathrm{P}(F^A = F^A{}_1)\, \mathrm{P}(D^A = D^A{}_U)$$

$$+ \mathrm{P}(r^A = r^A{}_L)\, \mathrm{P}(F^A = F^A{}_2)\, \mathrm{P}(D^A = D^A{}_U)\} \,/\, \mathrm{P}(C^A). \quad (15)$$

Now, (12) can be rewritten:

$$\mathrm{P}(r^B = r^B{}_L \mid C^A) - \mathrm{P}(r^B = r^B{}_L) = [\mathrm{P}((r^B = r^B{}_L) \mid (r^A = r^A{}_L)) - \mathrm{P}(r^B = r^B{}_L)]$$

$$* [P(r^A = r^A{}_L) P(F^A = F^A{}_2) P(D^A = D^A{}_U)] / P(C^A), \qquad (16)$$

and similarly, (15) can be rewritten:

$$P(r^A = r^A{}_L \mid C^A) - P(r^A = r^A{}_L) = [1 - P(r^A = r^A{}_L)]$$

$$* [P(r^A = r^A{}_L) P(F^A = F^A{}_2) P(D^A = D^A{}_U)] / P(C^A). \qquad (17)$$

Combining (16) and (17) yields (14).

In the other configurations, (14) still holds, while shrinking though. In Configuration 1, where $C^A \equiv (D^A = D^A{}_U)$, we have: $P(r^A = r^A{}_L \mid C^A) = P(r^A = r^A{}_L)$, which, together with (9), imply that the LHS and RHS in (14) are each equal to 0. Thus, (14) holds.

In Configuration 2, where $C^A \equiv (r^A = r^A{}_L) \cap (D^A = D^A{}_U)$, we have: $P(r^A = r^A{}_L \mid C^A) = 1$. It follows that (14) boils down to $P(r^B = r^B{}_L \mid C^A) = P(r^B = r^B{}_L \mid r^A = r^A{}_L)$, which is the equality leading to (10), thus, (14) is again true.

Last, in Configuration 4, where $C^A \equiv \{(F^A = F^A{}_1) \cap (r^A = r^A{}_L) \cap (D^A = D^A{}_U)\}$, we have again: $P(r^A = r^A{}_L \mid C^A) = 1$, and the argument is the same as above. This concludes the proof of Proposition 1. □

We see that the intensity of contagion is the sharpest possible for Configurations 2 and 4. Its size is:

$$P(r^B = r^B{}_L \mid C^A) - P(r^B = r^B{}_L) = [P(r^B = r^B{}_L \mid r^A = r^A{}_L) - P(r^B = r^B{}_L)], \qquad (18)$$

which reflects that the statistical relation is fully at work. The rationale is that, in either case, the materialization of a crisis reveals that $(r^A = r^A{}_L)$, unequivocally.

On the other hand, there is no contagion in Configuration 1. Indeed, a run being possible irrespectively of the realization of r^A, the occurrence of a run conveys no information on the early-liquidation yield in Country *A*, thus, neither in *B*.

Now, in Configuration 3, the size of contagion is lesser than (18), holding for cases 2 and 4. The reason is that the materialization of a run in *A* conveys only noisy information regarding r^A. Indeed, it is consistent with both "run possible irrespectively of realization of r^A" and "run possible if and only if $r^A = r^A_L$". Therefore, the statistical relation between the yields is somehow dampened by this uncertainty. We can further compute the size of contagion in this case:

$$\mathrm{P}(r^A = r^A_L \mid C^A) = \mathrm{P}(C^A \mid r^A = r^A_L)\, \mathrm{P}(r^A = r^A_L) / \mathrm{P}(C^A)$$

$$= 2q^A / (1 + q^A), \tag{19}$$

where we use: $\mathrm{P}(C^A) = ½\, p(1 + q^A)$, as computed in Subsection 3.4. Relation (14) then writes:

$$\mathrm{P}(r^B = r^B_L \mid C^A) - \mathrm{P}(r^B = r^B_L) = [\mathrm{P}(r^B = r^B_L \mid r^A = r^A_L) - \mathrm{P}(r^B = r^B_L)]\, q^A. \tag{20}$$

To encapsulate, both the statistical dependence of the yields and the extent of the downgrade in the catalyst country play a crucial role in the vulnerability to contagion and its intensity.

To conclude this section, it is worth noting that the previous two-economy model can be straightforwardly extended to more countries. The only amendment is that the Bayesian updating process of beliefs about the early-liquidation yield in a third country, say *C*, entails conditioning beliefs on the outcomes in both Countries *A* and *B*. And so on, when accounting for more countries.

6. Conclusion

This paper featured international contagion of bank runs in a third-generation model of financial crises through an informational channel. To do so, we capitalized on a model of financial crises by Chang and Velasco (2001), while focusing on debt rollover and taking a demand deposit system as given. We departed from that model by taking account of foreign creditors' expectations regarding being repaid and by introducing an informational edge of home depositors over foreign creditors regarding liquidation costs of assets. We then extended the resulting model to a two-country framework.

Our main findings have been the following. First, the probability of bank crisis increases with the subjective appraisal by foreign creditors of the chance that the early-liquidation yield takes a low value. Second, bank panics in a country may propagate to other countries, as foreign creditors reassess early-liquidation yields. Indeed, lenders bid lower prices to buy new debt issued by banks in those countries, which entails that those banks become more illiquid and are therefore more prone to runs. Third, both the degree of correlation between yields across countries and the strength of the Bayesian reassessment of the early-liquidation yield in the catalyst country play a crucial role in the vulnerability to contagion as well as its intensity.

While opening the door for the spread of bank runs and concomitant sudden reversals of capital flows, the model developed in this paper is not, strictly speaking, a model of contagion of twin crises, since it does not incorporate a monetary sector. A possible follow-up is thus to allow for the simultaneous spread of currency crises by bringing in a monetary sector. A second possible extension is paving the way for simultaneous drops in securities prices. Indeed, as pointed out in the introduction, collapses of asset values have often been observed in recent crises. Introducing collateralized borrowing in the model may be a step in the right direction. Another idea for a related paper is highlighting informational contagion in second-generation models of crises with an equilibrium selection mechanism *à la* Carlsson and van Damme (1993).

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