



# Correlated bank runs, interbank markets and reserve requirements



Carlos Cañón<sup>a</sup>, Paula Margaretic<sup>b,\*</sup>

<sup>a</sup> Banco de México, Financial Stability Division, Avenida 5 de Mayo No.1, 1er Piso, Colonia Centro, Delegacion Cuauhtemoc, Distrito Federal, Mexico

<sup>b</sup> Centre de Recherche en Management (CRM), Université Toulouse 1 Capitole, 6 Impasse du Ramier des Catalans, Batiment B, Apt. 202, 31000 Toulouse, France

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## ABSTRACT

This article extends the application of global games of Goldstein and Pauzner (2005) in the banking model of Diamond and Dybvig (1983) to account for correlation in the quality of banks' long term investment, when banks are linked through cross deposits and there is a central bank. The goal is to study how these elements affect the deposit contract that banks offer to depositors and the ex ante probability of a bank run. We show that the coexistence of a central bank, which determines banks' reserve requirements, and an interbank market, which redistributes reserves, leads to a smaller probability of a bank run and to fewer inefficient bank runs, relative to the case with no central bank and no interbank market. By adequately choosing the level of reserves to store, the central bank can improve the equilibrium outcome and allow banks to offer a higher interim payment to depositors, relative to the situation with no cross deposits.

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## 1. Introduction

The risk of bank runs is an inevitable feature of any banking system. Banks take short term deposits from lenders and make longer term investments. Since the pioneering work of Diamond and Dybvig in 1983, it is well understood that this “maturity transformation” is arguably the key function of a bank. On the downside, it brings with it the risk that depositors may ask for their money in large numbers at a time when the bank does not have the liquid resources to meet these demands.

This paper combines four elements of bank runs in reality to study how they affect the probability of a bank failure. The first element is the fact that information about the quality of banks' long-run investments is not perfect. The second element is the fact that the quality of banks' investments may be correlated. The third element is the fact that banks exchange cross deposits through the interbank market. The fourth one is the presence of a central bank which determines banks' reserve requirements.

The collapse of large financial institutions observed during the early stages of the global financial crisis of 2007–2012 illustrates the importance of imperfect information and correlation of banks'

investment strategies. In this regard, in a June, 9th 2008 speech, US Treasury Secretary Timothy Geithner, then President and CEO of the New York Federal Reserve Bank, referred to the freezing of credit markets observed some months before and placed significant blame on the run of entities in the banking system, being engaged in the same type of investment strategies, for which financial innovation had made it difficult to evaluate the quality of their investments.

Extending the application of global games of Goldstein and Pauzner (2005) and Margaretic and Pasten (2012), in the banking model of Diamond and Dybvig (1983), we examine how, in the presence of an interbank market and a central bank, imperfect information about the quality of banks' long-run investments, which can be correlated, affects the deposit contract that banks offer to depositors and the *ex-ante* probability of a bank run.<sup>1,2</sup>

As in Goldstein and Pauzner (2005) and Margaretic and Pasten (2012), we show that there is a unique Bayesian equilibrium, in

<sup>1</sup> Margaretic and Pasten (2012) extend Goldstein and Pauzner (2005) to investigate how correlation in the quality of banks' long run investment, together with sequentiality in the arrival of information, affect the probability of a bank run. Instead of one bank as in Goldstein and Pauzner, Margaretic and Pasten assume two banks.

<sup>2</sup> Wang (2013) introduces the government sector to the Goldstein and Pauzner (2005) model, to study how the announcement of bailouts affects the probability of a bank run.

\* Corresponding author. Tel.: +33 637174117.

E-mail addresses: [cannon@banxico.org.mx](mailto:cannon@banxico.org.mx) (C. Cañón), [paula.margaretic@airbus.com](mailto:paula.margaretic@airbus.com), [paumargaretic@gmail.com](mailto:paumargaretic@gmail.com) (P. Margaretic).

URL: <http://www.carloscaanon.com/> (C. Cañón).

which a bank run occurs if the quality of banks' long-run investments is below some threshold. What is nonetheless specific to our paper is that we demonstrate that the adequate interaction between the central bank and the interbank market can lead to a smaller probability of a bank run and to fewer inefficient bank runs, relative to the case with no central bank and no interbank market.

In our model, there are three periods, three regions and three banks. Each bank has a disjoint set of depositors.

The way we model correlation in the quality of banks' long run investments follows closely Margaretic and Pasten (2012). We assume that the quality of each bank's investment is stochastic and it can be identical to the quality of the other two banks with an exogenous probability. Depositors do not observe the realized quality, but instead, receive a noisy private signal about it.<sup>3</sup>

The way we model the interaction between depositors, banks, the interbank market and the central bank follows. In the initial period, the central bank, common to all regions, determines the fraction of deposits that banks must store as reserves, if they choose to participate in the interbank market. After observing this level of reserves, the three regional banks decide whether to participate or not. Next, they offer a demand deposit contract to all agents willing to deposit their endowment in the bank.

In the interim period, after observing the noisy private signal, depositors in the three regions decide simultaneously whether to withdraw their deposits or wait until the terminal period. The deposit contract offers a fixed interim payment, if early withdrawing; or a random payment, which is a fraction of the proceeds of the bank's long run, non-liquidated investment, if waiting until the terminal period.

The interbank market then allows banks with different needs for liquidity, to redistribute in the interim period the reserves stored by them in the first period. The reserves are redistributed through cross deposits; the central bank coordinates this redistribution.

If the bank does not run out of resources in the interim period, withdrawing the deposit in the terminal period has a higher expected return than early withdrawing. A bank runs out of resources, if total withdrawals in the interim period are higher than the liquidation value of its total long-run investment. Since the deposit contract follows a first-come-first-serve rule and there is no deposit insurance, if there is a run, early withdrawers may receive a payment, while late withdrawers receive nothing.

As in the standard global games result, we find that depositors in the three banks follow a trigger strategy, that is, they withdraw in the interim period if their signal is below a threshold. Our contribution is to show that an interbank market, which redistributes reserves, and a central bank, which determines banks' reserve requirements and coordinates their redistribution, can lead to a smaller probability of a bank run in all regions and to fewer inefficient bank runs, relative to the case with no interbank market and no central bank. The mechanism behind this crucial result works through depositors' beliefs, as follows.

The signal threshold for depositors is smaller if banks choose to participate in the interbank market. Intuitively, by redistributing reserves from liquid to illiquid banks, the interbank market provides banks with an insurance against the random interim demand of withdrawals. However, because of imperfect information about the quality of banks' investments, the insurance that the interbank market provides is incomplete. By adequately selecting the reserves to store and by coordinating the redistribution, the central bank improves that insurance. Depositors react to this double

insurance by updating their propensity to run, which reinforces the former mechanism and leads to a smaller probability of a run and to fewer inefficient bank runs.

One implication of this result is that the interbank market's capacity to redistribute reserves and to reduce the *ex-ante* probability of a bank run is decreasing in the probability that the quality of banks' long run investments is identical. In the extreme case, if banks' investments were of identical quality, depositors would receive similar private signals,<sup>4</sup> banks would have similar interim liquidity demand and there would be no reserves to redistribute.

We then study the way the central bank selects the fraction of reserves that banks must store, which in turn affects the interim payment that banks can afford to offer to depositors, contingent on participating in the interbank market.

We show that by adequately choosing the level of reserves to store, the central bank can improve the equilibrium outcome and enable banks to offer a higher interim payment to depositors, relative to the situation with no cross deposits. Since depositors are risk averse, a deposit contract offering a higher interim payment is *ex-ante* welfare improving to all agents.

This way, our paper provides a new rationale for the use of reserve requirements, as a macro prudential tool, to achieve financial stability, when the quality of banks' investments is correlated. From a policy standpoint, when choosing the reserves to store, the central bank should take into account the precision of information, the term structure of interest rates and crucially, the pattern of correlation. While the first two elements have been subject of both theoretical and empirical debate, regulators and policy makers do not seem sufficiently aware of the importance of correlation in the quality of banks' investments, when designing banking regulation to strengthen financial stability. This is unsuitable, because as we show, the effectiveness of reserve requirements to reduce the probability of a bank run also depends on this correlation.

The paper proceeds as follows. Section 2 outlines the contribution to the literature. Section 3 presents the model and discusses its main features. Section 4 studies the problem of depositors at the interim period. Section 5 analyses the problem of banks and that of the central bank, at the initial period. Section 6 discusses some policy implications. Concluding remarks are in Section 7. All proofs are relegated to Appendix A.

## 2. Relation to the literature

There is an immense literature on banks and bank runs. Although it cannot be fully covered here, in the following lines, we highlight the paper closest to ours and four strands of literature that are linked to our work.

The paper closest to ours is Margaretic and Pasten (2012). To our knowledge, they were the first to extend Goldstein and Puzner (2005)'s global games application, to account for correlation in the quality of banks' investment. Adding sequentiality in the arrival of information, they show that sequential bank runs are possible, that is, there is a higher probability of a run in the second bank, if there is a run in the first bank, than if there is no run. We share with them the importance given to correlation. We depart from them, because instead of focusing on the informational link that sequentiality creates, we focus on the link that an interbank market and a central bank create.

First, there is a wide literature on systemic risk and how its nature affects the occurrence and propagation of financial crisis. On the one hand, Allen and Gale (2000), Freixas et al. (2000) and Allen et al. (2010) analyze the risk of contagion, where the failure

<sup>3</sup> The importance of correlation has also been stressed by Acharya and Yorulmazer (2007), Acharya (2009), and Farhi and Tirole (2012). See next section, relation to the literature.

<sup>4</sup> Private signals are noisy. We allow for some (but not any) imprecision in private signals.

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