Global Games and Financial Fragility: Foundations and a Recent Application

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Outline

Part I:

The introduction of global games into the analysis of financial fragility and crises

Part II:

A recent application, based on a paper "The Interdependence of Bank Capital and Liquidity" (with Elena Carletti and Agnese Leonello)
Financial Fragility and Coordination Failures

- What makes financial systems fragile? What causes crises and breakdowns in financial institutions and markets?

- A primary source for fragility is: coordination failures

- A coordination failure arises when economic agents take a destabilizing action based on the expectation that other agents will do so as well. The result is a self-fulfilling crisis

- The key ingredient for this to arise is strategic complementarities: agents want to do what others do
Leading Example: Bank Runs

- Diamond and Dybvig (1983): Banks Create liquid claims on illiquid assets using demand-deposit contracts
- Arrangement leads to two equilibria:
  - **Good equilibrium:** only impatient agents demand early withdrawal
  - **Bad equilibrium:** all agents demand early withdrawal. **Bank Run** occurs
- Bank runs occur because of strategic complementarities:
  - When everyone runs on the bank, this depletes the bank’s resources, and makes running optimal. As a result, runs are **panic-based**
Problems with Multiplicity

- The model provides no tools to determine when runs will occur. This is an obstacle for:
  - **Understanding bank choices:**
    - What will be the equilibrium choices of banks, e.g., liquidity provision, when they take into account the possibility of a run and how it is affected by their choices?
  - **Policy analysis:** which policy tools are desirable to overcome crises?
- Deposit insurance is perceived as an efficient tool to prevent bank runs, but it might have costs, e.g., moral-hazard
- Without knowing how likely bank runs are, it is hard to assess the desirability of deposit insurance

  **Empirical analysis:** what constitutes sufficient evidence for the relevance (or lack of) of strategic complementarities in fragility?

- Large body of empirical research associates crises with weak fundamentals. Is this evidence against the panic-based approach?
- How can we derive empirical implications?
The Global-Games Approach

- The global-games approach – based on Carlsson and van Damme (1993) – enables us to derive a unique equilibrium in a model with strategic complementarities and thus overcome the problems associated with multiplicity of equilibria.

- The approach assumes that the fundamentals of the bank may be in extreme dominance regions and that agents observe slightly noisy signals of them.

- A simple illustration is provided by Morris and Shin (1998).
Equilibrium with Global Games: Step I

- Assuming the existence of dominance regions:
Equilibrium with Global Games: Step II

- Assuming slightly noisy signals:

A run occurs if and only if the fundamentals are below a unique threshold

\[ \theta \leq \theta^* \leq \bar{\theta} \]
Working with Global-Games Equilibrium

- Run probability captured by threshold $\theta^*$, which is characterized by indifference condition of marginal agent
- Analyzing this condition, one can:
  - Characterize banks’ choices and their interaction with run probability (Goldstein and Pauzner, 2005)
  - Conduct policy analysis (Allen, Carletti, Goldstein, and Leonello, 2018)
  - Derive and test empirical predictions (Chen, Goldstein, and Jiang, 2010)
The Interdependence of Bank Capital and Liquidity

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Disclaimer: The views expressed here are the authors’ and do not reflect those of the ECB or the Eurosystem
Introduction

- Liquidity played a central role in the recent financial crises (e.g., Bernanke, 2008)
- As a result, liquidity regulation (e.g., LCR and NSFR) was introduced to complement capital regulation
- Capital and liquidity requirements are meant to serve different purposes
  - The former deals with solvency issues, the latter with liquidity ones
- (In)solvency and (il)liquidity are closely intertwined concepts
- In light of these considerations, do capital and liquidity interact in affecting bank stability? If so, how?
What we do in the paper

- We present a model to analyze the interdependent effect of capital and liquidity on financial stability

- What is needed:
  - Endogenize crises probability to see how it is affected by banks’ balance sheet choices
  - Endogenize banks’ balance sheet choices to see how they are affected by regulation, taking into account investors’ expected run behavior

- We put all these ingredients together and derive new results on the effects of capital and liquidity on bank stability and some implications for capital and liquidity regulation

Literature
Our paper

- Builds on the model by Goldstein and Pauzner (2005) (GP, 2005), where
  - Depositors’ withdrawal decisions are uniquely determined using the global-game methodology
    - Runs occur when the fundamentals are below a unique threshold
  - Crisis probability is endogenous and depends on bank choice of the deposit contract
    - Banks are only deposit financed
- In our framework, the probability of a bank failure depends both its balance sheet choices and overall market conditions
  - Bank funding comes from both equity and debt
  - Banks choose their portfolio liquidity
  - Asset liquidation value depends on a bank liquidity choice and that of all other banks in the economy
What we do in details

- We start from one bank and
  - Disentangle the effect of capital and liquidity on run probabilities
  - Identify inefficiency of the unregulated equilibrium
  - Characterize optimal micro-prudential regulation

- In the case with multiple bank, we show that
  - Banks are linked as they sell assets in a common asset market
  - The existence of a common asset market affects crisis probability, banks’ choices and inefficiency; and
  - Characterize optimal macro-prudential regulation (in progress)
Results in a nutshell

- Capital and liquidity may have detrimental effects on crisis probability, depending on banks’ asset liquidity and capital structure
  - Regulation should consider both sides of bank balance sheet
- Banks choose to be exposed to inefficient crises
  - Crises destroy good investments
- Capital and liquidity regulation are substitutes from a micro-pru perspective
- In a multiple bank setting, fire sales increase the probability of a crisis (contagion) and cost of premature liquidation
- Both capital and liquidity regulation are necessary from a macro-pru perspective
  - Capital regulation reduces inefficient crisis
  - Liquidity regulation reduces fire sales
The baseline model: Banks and investors

- Three dates \((t = 0, 1, 2)\) economy with a bank and a continuum \([0, 1]\) of (risk-neutral) investors
- At date 0, the bank raises a fraction \(k\) as capital and \(1 - k\) as short-term debt, and invests in a risky portfolio
  - Capital entails a per unit cost \(\rho > 1\)
  - Debt holders are promised \(r_1 = 1\) at date 1 and \(r_2 \geq 1\) at date 2 in case of rollover and must obtain at least 1 in expectation
- Portfolio returns \(\ell \in [0, 1]\) at date 1 and \(R(\theta) (1 - \alpha \ell)\) at date 2, where
  - \(\ell\) is a choice variable capturing bank portfolio liquidity \(\rightarrow\) liquidity/return trade-off
  - \(\theta \sim U[0, 1], R'(\theta) > 0\) and \(0 < \alpha \leq \bar{\alpha}\) is cost of liquidity
The baseline model: debt holders’ information

- At the beginning of date 1, each debt holder receives a private signal $s_i$ on the fundamental of the economy of the form

$$s_i = \theta + \epsilon_i$$

with $\epsilon_i \sim U[-\epsilon, +\epsilon]$ being i.i.d. across agents and $\epsilon \to 0$

- Based on the signal, debt holders decide whether to withdraw (run) at date 1 or roll over their debt
  - They update their beliefs about $\theta$ and the others’ actions

- The bank satisfies early withdrawals by liquidating its portfolio

- Debt holders receive a pro-rata share, whenever bank proceeds are not enough to repay $r_1$ or $r_2$
Payoffs to early and late withdrawal

- Debt holders choose the action that gives them the highest payoff
  - Both $\theta$ and $n$ matter (strategic complementarity)
Debt holders’ rollover decision and crises

<table>
<thead>
<tr>
<th>Fundamental crises</th>
<th>Panic crises</th>
<th>No crises</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>θ</td>
<td>1</td>
</tr>
<tr>
<td>debt holders</td>
<td>debt holders</td>
<td>no debt holders</td>
</tr>
<tr>
<td>withdraw as low θ</td>
<td>withdraw because of θ and n</td>
<td></td>
</tr>
</tbody>
</table>

where \( \theta \) is the solution to

\[
R(\theta) (1 - \alpha \ell) = (1 - k) r_1
\]

and \( \theta^* \) to

\[
\int_{n=0}^{\hat{n}(\theta)} r_2 + \int_{n=\hat{n}(\theta)}^{\tilde{n}} \frac{R(\theta) (1 - \alpha \ell) \left[1-\frac{(1-k)nr_1}{\ell}\right]}{(1-k)(1-n)} = \int_{n=0}^{\tilde{n}} r_1 + \int_{n=\tilde{n}}^{1} \frac{\ell}{(1-k)n}
\]
The effect of capital on crisis probability

- **Capital** is ambiguous for crises due to two opposing effects

\[
- \int_{\hat{n}(\theta)}^{\bar{n}} \frac{R(\theta)(1 - \alpha \ell)}{(1 - k)(1 - n)} \, dn + \int_{\bar{n}}^{1} \frac{\ell}{(1 - k)n} \, dn
\]

Higher repayment at date 2

Higher repayment at date 1

- Initial balance sheet composition (i.e., \( k \) and \( \ell \)) determines which effect dominates
The effect of liquidity on crisis probability

- Liquidity is **ambiguous** for crises due to three different effects:

\[
- \int_{\hat{n}(\theta)}^{\bar{n}} \frac{R(\theta) n r_1}{\ell^2 (1 - n)} \, dn + \int_{\hat{n}(\theta)}^{\bar{n}} \frac{\alpha R(\theta)}{(1 - k) (1 - n)} \, dn + \int_{\bar{n}}^{1} \frac{1}{(1 - k) n} \, dn
\]

  - Higher repayment at date 2 due to less liquidation at date 1
  - Lower repayment at date 2 due to lower profitability
  - Higher repayment at date 1

- Again, initial balance sheet composition (i.e., \(k\) and \(\ell\)) determines which effect dominates.
The bank’s choice

- Given debt holders’ rollover decisions, at date 0 each bank chooses $k$, $\ell$ and $r_2$ to maximize

\[
\Pi^B = \int_{\theta^*}^{1} [R(\theta)(1 - \alpha\ell) - (1 - k)r_2] d\theta - k\rho
\]

subject to

\[
\int_{0}^{\theta^*} \frac{\ell}{(1 - k)} d\theta + \int_{\theta^*}^{1} r_2 d\theta \geq 1 \text{ and } \Pi^B \geq 0
\]

- The choice of $(k, \ell)$ trades-off their impact on runs, funding costs and portfolio returns
  - Banks choose to be exposed to liquidity crises
  - Inefficiency: crises entail premature liquidation of profitable investments
Capital, liquidity and bank fragility

- When \((1 - k) = \ell\) (i.e., for \(k = k^{\text{max}}(\ell)\)), there are no strategic complementarities (i.e., \(\theta^* \rightarrow \bar{\theta}\)) and crises are efficient (i.e., \(\bar{\theta} \equiv \bar{\theta}^E\))

![Graph showing the relationship between capital and liquidity where the bank fails for \(\theta < \theta^*\) and liquidation is inefficient.](image)
Effect of capital on crisis probability

- Banks never choose to be where capital increases crisis probability

\[ k \]

Capital is detrimental for bank stability

\[ k^{max}(\ell) \]

Capital is beneficial for bank stability

\[ \tilde{k}(\ell) \]
Effect of liquidity on crisis probabilities

- Banks never choose to be where liquidity increases crisis probability

Figure 4: Caption
Regulatory intervention

- Regulator sets capital and liquidity requirements (i.e., $k^R$ or $\ell^R$) to minimize

$$\int_{\theta^E}^{\theta^*} [R(\theta)(1 - \alpha \ell) - \ell] \, d\theta$$

subject to

$$r_2^B = \arg \max \Pi^B, \Pi^B \geq 0$$

- Then, it sets requirements so that $(1 - k^R) = \ell^R$ holds
  - The exact point on $(1 - k^R) = \ell^R$ frontier depends on how costly $k$ and $\ell$ are for banks

- Capital and liquidity are substitutes in restoring efficiency if adequately designed
Banks in the system

- Two banks \((i = A, B)\) with the same \(\theta\) (aggregate shock)
- They sell assets to outside investors with finite wealth and ability \(w\) in a common asset market
- Now, bank \(i\) liquidation value is \(\ell^i \ast \chi\), where \(\chi\) depends on investors’ wealth \(w\) and total amount of illiquid assets sold \(Q\)

\[
\chi(Q, w) = \begin{cases} 
1 & \text{if } Q \leq w \\
h(Q) & \text{if } Q > w
\end{cases},
\]

with \(h(Q) < 1\), \(h'(Q) < 0\) and \(Q'_\ell < 0\)

- A debt holder in bank \(A\) cares about what debt holders do in bank \(B\) because it affects \(Q\) and so the bank’s liquidation needs via \(\chi(Q, w)\)

- **Between** banks strategic complementarities emerge on top of **within** bank ones
Equilibrium with fire sales

- The model has still a unique threshold equilibrium
  - Debt holders run if $\theta < \theta_F^*$ and do not above, with $\theta_F^* \geq \theta^*$
  - Some crises are only driven by fire sales (contagion)

<table>
<thead>
<tr>
<th></th>
<th>Individual bank failure</th>
<th>Contagion</th>
<th>No crises</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Banks fail</td>
<td>Banks fail</td>
<td>no banks</td>
</tr>
<tr>
<td></td>
<td>because of $n$</td>
<td>because of the other bank’s $n$</td>
<td>fail</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td>no banks</td>
</tr>
</tbody>
</table>
Banks’ choice

▶ Banks problem is as before, but
  ▶ Crisis threshold is $\theta^*_F$
  ▶ Debt holders receive $\frac{\ell \chi(Q^{tot}, w)}{(1-k)}$ in the event of a run
▶ As before, banks choose to be exposed to liquidity crises
▶ **But**, bank solution now entails two inefficiencies:
  ▶ Inefficient liquidation of good projects:
    \[
    \int_{\theta^*}^{\theta_F} \left[ R(\theta) (1 - \alpha\ell) - \ell \right] d\theta
    \]
  ▶ Fire-sales losses:
    \[
    \int_{0}^{\theta^*_F} \ell \left[ 1 - \chi(Q^{tot}, w) \right] d\theta
    \]
Regulatory intervention

- Regulator sets capital and liquidity requirements \( \{ k^R, \ell^R \} \) to minimize

\[
TL = \int_{\theta^E}^{\theta^*_{F}} [R(\theta)(1-\alpha\ell) - \ell] \, d\theta + \int_{0}^{\theta^*_{F}} \ell \left[ 1 - \chi(Q^{tot}, w) \right] \, d\theta
\]

subject to

\[
r_{2}^{B} = \arg \max \Pi^{B}, \Pi^{B} \geq 0
\]

- One tool is no longer enough
  - Eliminating liquidity crises (i.e., imposing \( (1-k) = \ell \chi(.) \)) still leaves inefficient liquidation and fire sales losses (i.e., \( \theta^*_{FS} \to \theta > \theta^E \) and \( \chi = \chi(Q^{tot}, w) < 1 \))
  - Banks must be forced to hold a sufficient amount of liquidity so that \( \chi = 1 \) and capital should be set to satisfy \( (1-k) = \ell \)
    - But, this may not feasible if \( \alpha \) and \( \rho \) are large as constraint \( \Pi^{B} \geq 0 \) binds
Conclusions

- In the absence of regulation, banks choose to be exposed to inefficient liquidity crises
- From a micro perspective, capital and liquidity regulation are substitutes in restoring efficiency
- From a macro perspective, both capital and liquidity regulation are needed
- It may not be feasible if market conditions are tight and capital and liquidity are costly for banks
Liquidity regulation

- Liquidity Coverage Ratio (LCR) aims at improving banks’ ability to withstand large withdrawals
  
  \[
  \frac{\text{Stock of } HQLA}{\text{Total net cash outflows over 30 days}} \geq 100\%
  \]

  - Total net cash outflows computed by applying weights to different types of liabilities
  - Introduced in 2015, but full implementation from 01.01.2019

- Net Stable Funding Ratio (NSFR) aims at improving banks’ resilience
  
  \[
  \frac{\text{Total available stable funding (ASF)}}{\text{Total required stable funding (RSF)}} \geq 100\%
  \]

  - ASF and RSF computed by assigning weights to different types of liabilities and assets, respectively, based on runnability and liquidity
  - Applicable to internationally active banks from 01.01.2018
(Some) Related literature

▶ **Liquidity regulation**
  ▶ Diamond and Kashyap (2016): DD(1983) plus depositors having incomplete info about bank’s ability to survive a run. LCR and NSFR reduce run probability, but do not correspond to optimal regulation
  ▶ König (2015): Rochet and Vives (2004) and Vives (2014) plus liquid assets earning lower return on average than illiquid ones. Liquidity regulation may lead to more runs

▶ **Capital and liquidity regulation**
  ▶ Calomiris, Heider and Hoerova (2015): bankers need to exert costly effort to make loan portfolio safe. **Liquidity curbs moral hazard problem** when equity is scarce. Regulation is only needed when depositors’ discipline is limited
  ▶ Kashyap, Tsomocos and Vardoulakis (2017): Bank run model plus bank’s asset side risk choice. **Regulations always reduce run probability**, but none achieve the efficient allocation
Solvency crises

- For any $\theta \leq \bar{\theta}$, withdrawing early is a dominant strategy
  - Crises are only due to bad realization of $\theta$
Liquidity crises

- For any $\theta > \theta$, withdrawing early is only optimal if $\theta \leq \theta^*$
  - Crises are only due to fear of high $n$, i.e., coordination failure
Bank FOC

► FOC k

\[
- \frac{\partial \theta^*}{\partial k} \left[ R(\theta)(1 - \alpha \ell) - (1 - k)r_2 \right] + \int_{\theta^*}^{1} r_2 d\theta - \rho \\
+ \frac{dr_2}{dk} \left[ \int_{\theta^*}^{1} (1 - k) d\theta - \frac{\partial \theta^*}{\partial r_2} \left[ R(\theta)(1 - \alpha \ell) - (1 - k)r_2 \right] \right] = 0
\]

► FOC \ell

\[
- \frac{\partial \theta^*}{\partial \ell} \left[ R(\theta)(1 - \alpha \ell) - (1 - k)r_2 \right] + \int_{\theta^*}^{1} r_2 d\theta - \rho \\
+ \frac{dr_2}{d\ell} \left[ \int_{\theta^*}^{1} (1 - k) d\theta - \frac{\partial \theta^*}{\partial r_2} \left[ R(\theta)(1 - \alpha \ell) - (1 - k)r_2 \right] \right] = 0
\]
Reaction functions

Figure 7: Caption