Financial Fragility

A Global-Games Approach

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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: c**oordination 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.

Bank Runs: Diamond and Dybvig (1983)

- Banks Create liquid claims on illiquid assets using **demand-deposit contracts**.
    - Enable investors with early liquidity needs to participate in long-term investments. Provide **risk sharing**.
- Arrangement leads to two equilibria:
    - **Good equilibrium:** only impatient agents demand early withdrawal.
        - Clear improvement over autarky. First-best is achieved.

- **Bad equilibrium:** all agents demand early withdrawal. **Bank Run** occurs.
  - Inferior outcome to autarky. No one gets access to long-term technology and resources are allocated unequally.

- Bank runs occur because of strategic complementarities:
  - When everyone runs on the bank, this depletes the bank's resources, and makes running the optimal choice.

- As a result, runs are **panic-based**: They occur as a result of the **self-fulfilling beliefs** that other depositors are going to run.

Problems with Multiplicity

- The model provides no tools to determine when runs will occur.
- This is an obstacle for:
  - **Understanding liquidity provision and runs:**
    - How much liquidity will banks offer when they take into account the possibility of a run and how it is affected by the banking contract?
    - Given that banks may generate a good outcome and a bad outcome, it is not clear if they are even desirable overall.

- **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? See Goldstein (2012).

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 (discussed above).

- The approach assumes **lack of common knowledge** obtained by assuming that agents observe slightly noisy signals of the fundamentals of the economy.

- A simple illustration is provided by Morris and Shin (1998).

A Model of Currency Attacks

- There is a continuum of speculators *[0,1]* and a government.
- The exchange rate without intervention is $f(\theta)$, where $f'(\theta) > 0$, and θ, the fundamental of the economy, is uniformly distributed between *0* and *1*.
- The government maintains the exchange rate at an over-appreciated level (due to reasons outside the model): $e^* > f(\theta), \forall\theta$.
- Speculators may choose to attack the currency.

- The cost of attack is t (transaction cost).
- The benefit in case the government abandons is $e^* - f(\theta)$.
  - In this case, speculators make a speculative gain.

- The government's payoff from maintaining is: $v - c(\alpha, \theta)$.
  - v can be thought of as reputation gain.
    - $c(\alpha, \theta)$ is increasing in α (proportion of attackers) and decreasing in θ: Cost increases in loss of reserves and decreases in fundamentals.

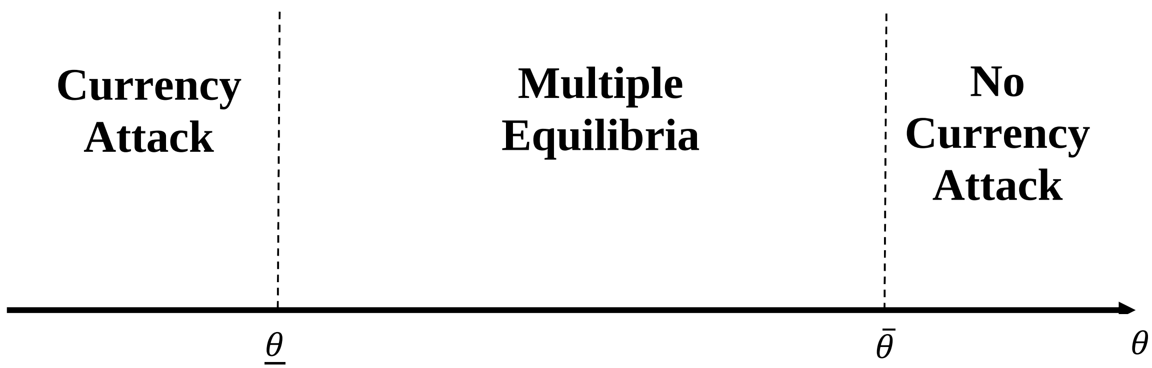
Equilibria under Perfect Information

- Suppose that all speculators (and the government) have perfect information about the fundamental θ.

- Define extreme values of θ, $\underline{\theta}$ and $\overline{\theta}$: $1 > \overline{\theta} > \underline{\theta} > 0$, such that:
  - $c\left(0, \underline{\theta}\right) = v$.
  - $e^* - f\left(\overline{\theta}\right) = t$.
  - Below $\underline{\theta}$, the government always abandons. Above $\overline{\theta}$, attack never pays off.

- Three ranges of the fundamentals:
  - When $\theta < \underline{\theta}$, unique equilibrium: all speculators attack.
  - When $\theta > \overline{\theta}$, unique equilibrium: no speculator attacks.
  - When $\overline{\theta} > \theta > \underline{\theta}$, multiple equilibria: Either all speculators attack or no speculator attacks (for this, assume $c(1,1) > v$).
- As in Diamond and Dybvig, the problem of multiplicity comes from strategic complementarities: when others attack, the government is more likely to abandon, increasing the incentive to attack.

- Equilibria in the basic model:



Introducing Imperfect Information

- Suppose that speculator i observes $\theta_i = \theta + \varepsilon_i$, where ε_i is uniformly distributed between $-\varepsilon$ and ε. (Government has perfect information.)

- Speculators choose whether to attack or not based on their signals.

- The key aspect is that because they only observe imperfect signals, they must take into account what others will do at other signals.

- This will ‘connect’ the different fundamentals and determine optimal action at each.

Definitions

- Payoff from attack as function of fundamental and aggregate attack:

$$h\big(\theta,\alpha(\theta)\big) = \begin{cases} e^* - f(\theta) - t & if \quad \alpha(\theta) > a(\theta) \\ -t & if \quad \alpha(\theta) \leq a(\theta) \end{cases},$$

where $c(a(\theta),\theta) = v$.

- Payoff as a function of the signal and aggregate attack:

$$V\big(\theta_i,\alpha(\theta)\big) = \frac{1}{2\varepsilon}\int_{\theta_i-\varepsilon}^{\theta_i+\varepsilon} h\big(\theta,\alpha(\theta)\big)d\theta$$

- Threshold strategy characterized by θ' is a strategy where the speculator attacks at all signals below θ' and does not attack at all signals above θ'.
    - Aggregate attack when speculators follow threshold θ':

$$\alpha(\theta,\theta') = \begin{cases} 0 & if \quad \theta > \theta' + \varepsilon \\ \dfrac{\theta' + \varepsilon - \theta}{2\varepsilon} & if \quad \theta' - \varepsilon \le \theta \le \theta' + \varepsilon \\ 0 & if \quad \theta < \theta' - \varepsilon \end{cases}$$

- We will show that there is a unique threshold equilibrium and no non-threshold equilibria that satisfy the Bayesian-Nash definition.

Existence and Uniqueness of Threshold Equilibrium

- Let us focus on the incentive to attack at the threshold:
  - Function $V\left(\theta', \alpha(\theta, \theta')\right)$ is monotonically decreasing in θ'; positive for low θ' and negative for high θ'.
  - Hence, there is a unique θ^* that satisfies $V\left(\theta^*, \alpha(\theta, \theta^*)\right) = 0$.
  - This is the only candidate for a threshold equilibrium, as in such an equilibrium, at the threshold, speculators ought to be indifferent between attacking and not attacking.

- To show that acting according to threshold θ^* is indeed an equilibrium, we need to show that speculators with lower signals wish to attack and those with higher signals do not wish to attack.
  - This holds because: $V\left(\theta_i, \alpha(\theta, \theta^*)\right) > V\left(\theta^*, \alpha(\theta, \theta^*)\right) = 0$, $\forall\theta_i < \theta^*$, due to the direct effect of fundamentals (lower fundamental, higher profit and higher probability of abandoning) and that of the attack of others (lower fundamental, more people attack and higher probability of abandoning).
  - Similarly, $V\left(\theta_i, \alpha(\theta, \theta^*)\right) < V\left(\theta^*, \alpha(\theta, \theta^*)\right) = 0$, $\forall\theta_i > \theta^*$,

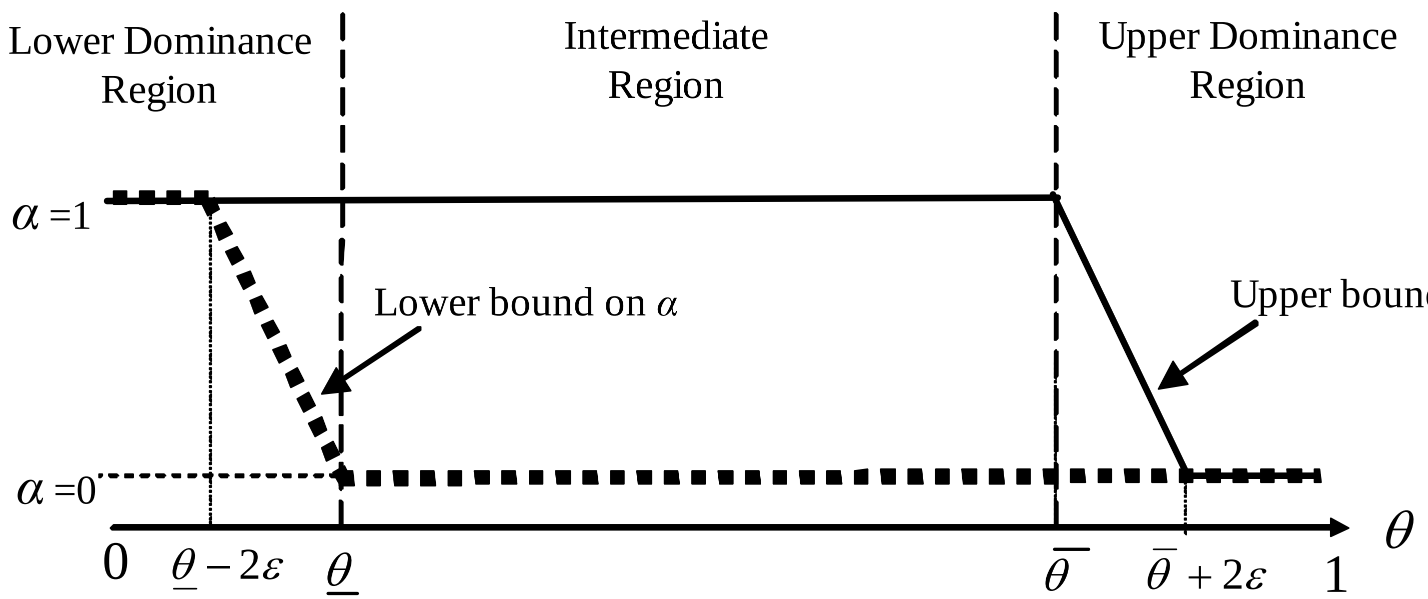
Ruling out Non-Threshold Equilibria

- These are equilibria where agents do not act according to a threshold strategy.
- By contradiction, assume such an equilibrium and suppose that speculators attack at signals above θ^*; denote the highest such signal as θ'^* (we know it is below 1 because of upper dominance region).
- Denote the equilibrium attack as $\alpha'(\theta)$, then due to indifference at a switching point: $V\left(\theta'^*, \alpha'(\theta)\right) = 0$.
- We know that $\alpha'(\theta) \leq \alpha(\theta, \theta'^*)$.

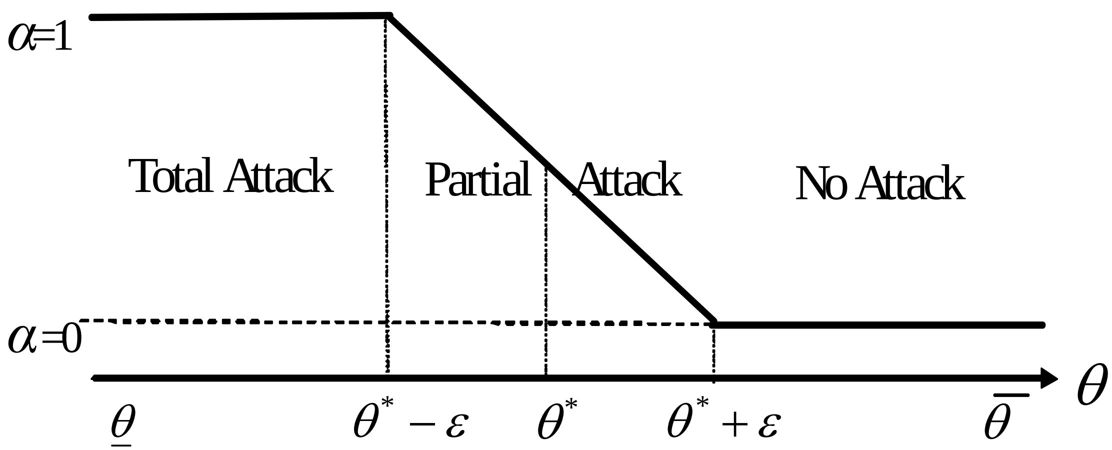
- Then, due to strategic complementarities: $V\left(\theta'^{*}, \alpha(\theta, \theta'^{*})\right) \geq 0$.
- But, this is in contradiction with $V\left(\theta^{*}, \alpha(\theta, \theta^{*})\right) = 0$, since θ'^{*} is above θ^{*} and function $V\left(\theta', \alpha(\theta, \theta')\right)$ is monotonically decreasing in θ'.
- Hence, speculators do not attack at signals above θ^{*}.
- Similarly, one can show that they always attack at signals below θ^{*}.
- This rules out equilibria that are different than a threshold equilibrium, and establishes the threshold equilibrium based on θ^{*} as the unique equilibrium of the game.

Some Intuition

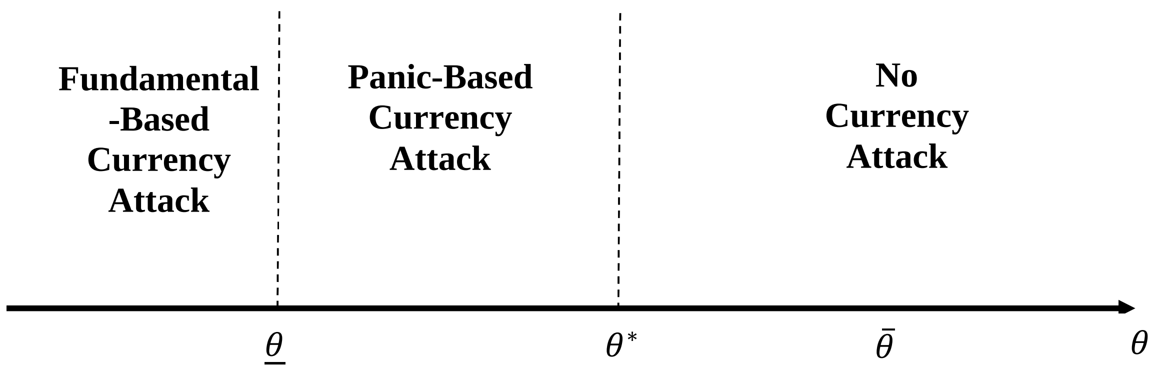
- These are the bounds on the proportion of attack imposed by the dominance regions:



- These bounds can be shifted closer together by iterative elimination of dominated strategies.
- The result is the equilibrium that we found:



- Or, when the noise converges to zero:



Important:

- Although θ uniquely determines α, attacks are still driven by bad expectations, i.e., still panic-based:
  - In the intermediate region speculators attack because they believe others do so.
  - θ acts like a coordination device for agents' beliefs.
- A crucial point: θ is not just a sunspot, but rather a payoff-relevant variable.
  - Agents are obliged to act according to θ.

Why Is This Equilibrium Interesting?

- **First**, reconciles panic-based approach with empirical evidence that fundamentals are linked to crises.
- **Second**, panic-based approach generates empirical implications.
    - Here, the probability of a crisis is pinned down by the value of θ^*, affected by variables t, v, etc. based on: $V\left(\theta^*, \alpha(\theta, \theta^*)\right) = 0$.
- **Third**, once the probability of crises is known, one can use the model for policy implications.
- **Fourth**, captures the notion of strategic risk, which is missing from the perfect-information version.

Back to Bank Runs: Goldstein and Pauzner (2005)

- Use global-games approach to address the fundamental issues in the Diamond-Dybvig model.
- But, the Diamond-Dybvig model violates the basic assumptions in the global-games approach. It does not satisfy **global strategic complementarities**.
    - Derive new proof technique that overcomes this problem.
- Once a unique equilibrium is obtained, study how the probability of a bank run is affected by the banking contract, and what is the optimal demand-deposit contract once this is taken into account.

Model

- There are three periods (*0*, *1*, *2*), one good, and a continuum *[0,1]* of agents.
- Each agent is born at period *0* with an endowment of *1*.
- Consumption occurs only at periods *1* or *2*.
- Agents can be of two types:
  - Impatient (probability λ) – enjoys utility $u(c_1)$,
  - Patient (probability $1\text{-}\lambda$) – enjoys utility $u(c_1 + c_2)$.

- Types are i.i.d., privately revealed to agents at the beginning of period *1*.

- Agents are highly risk averse. Their relative risk aversion coefficient:

$$-\frac{cu''(c)}{u'(c)} > 1 \text{ for any } c \geq 1.$$

  - This implies that $cu'(c)$ is decreasing in c for $c \geq 1$, and hence $cu'(c) < u'(1)$ for $c > 1$.

  - Assume $u(0) = 0$.

- Agents have access to the following technology:

  - *1* unit of input at period *0* generates *1* unit of output at period *1* or *R* units at period *2* with probability $p(\theta)$.

  - θ is distributed uniformly over *[0,1]*. It is revealed at period *2*.

  - $p(\theta)$ is increasing in θ.

  - The technology yields (on average) higher returns in the long run:

$$E_\theta[p(\theta)]u(R) > u(1).$$

First-Best Risk Sharing

- Period-1 consumption of impatient agents: c_1.
- Period-2 consumption of patient agents is the remaining resources: $c_2 = \frac{(1-\lambda c_1)}{1-\lambda} R$ (with probability $p(\theta)$).
- Set c_1 to maximize expected utility:

$$\lambda u(c_1) + (1-\lambda) u\left(\frac{(1-\lambda c_1)}{1-\lambda} R\right) E_\theta[p(\theta)]$$

- First order condition:

$$u'(c_1^{FB}) = Ru'\left(\frac{(1-\lambda c_1^{FB})}{1-\lambda}R\right)E_\theta[p(\theta)]$$

- Banks can provide risk sharing by offering a short-term payment r_1 to every agent who claims to be impatient.
- If there are no runs, then it is optimal to set $r_1 = c_1^{FB}$.
- Otherwise, need to see how r_1 affects run probability, and how this affects optimal r_1.
- Banks follow a sequential service constraint:

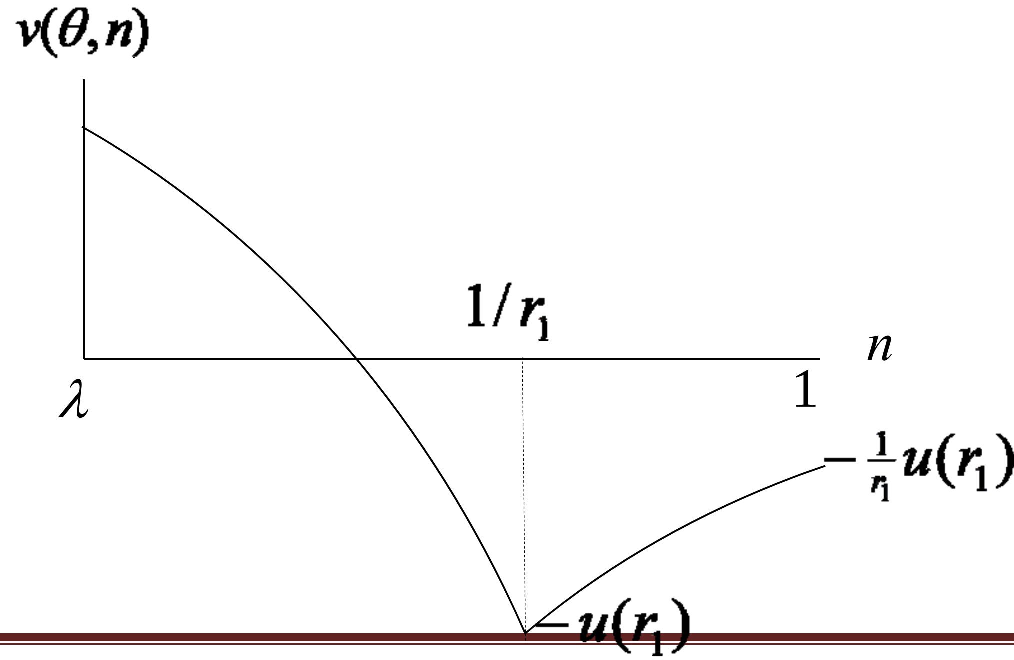
  - They pay r_1 to agents who demand early withdrawal as long as they have resources.
  - If too many agents come and they run out of resources, they go bankrupt, and remaining agents get no payment.

- Impatient agents demand early withdrawal since they have no choice. Patient agents have to consider the payoff matrix shown in the next slide.
- Information structure similar to Morris-Shin: depositor i observes signal $\theta_i = \theta + \varepsilon_i$, where ε_i is uniformly distributed between $-\varepsilon$ and ε.

Action	$n < 1/r_1$	$n \geq 1/r_1$
Run	r_1	$\begin{cases} r_1 & prob \quad \frac{1}{nr_1} \\ 0 & prob\ 1 - \frac{1}{nr_1} \end{cases}$
No Run	$\begin{cases} \frac{(1-nr_1)}{1-n}R & prob \quad p(\theta) \\ 0 & prob\ 1 - p(\theta) \end{cases}$	0

Here, n is the proportion of agents (patient and impatient who demand early withdrawal.

- Global strategic complementarities do not hold:
  - An agent's incentive to run is highest when n=$1/r_1$ rather than when $n = 1$.
- Graphically:



- The proof of uniqueness builds on **one-sided strategic complementarities**:
  - v is monotonically decreasing whenever it is positive
- which implies **single crossing**:
  - v crosses zero only once.
- Show uniqueness by:
  - Showing that there exists a unique threshold equilibrium.
  - Showing that every equilibrium must be a threshold equilibrium.

The Demand-Deposit Contract and the Viability of Banks

- We can now characterize the threshold as a function of the rate offered by banks for early withdrawals. At the limit, as ε approaches zero, $\theta^*(r_1)$ is defined by:

$$\int_{n=\lambda}^{1/r_1} u(r_1) + \int_{n=1/r_1}^{1} \frac{1}{nr_1} u(r_1) = \int_{n=\lambda}^{1/r_1} p(\theta^*) u\left(\frac{(1-nr_1)}{1-n} R\right)$$

  - At the threshold, a patient agent is indifferent.
  - His belief at this point is that the proportion of other patient agents who run is uniformly distributed. Effectively, there is no fundamental uncertainty (only strategic uncertainty).

- Analyzing the threshold $\theta^*(r_1)$ with the implicit function theorem, we can see that it is increasing in r_1.
  - The bank becomes more vulnerable to bank runs when it offers more risk sharing.

- Intuition:
  - With a higher r_1 the incentive of agents to withdraw early is higher.
  - Moreover, other agents are more likely to withdraw at period 1, so the agent assesses a higher probability for a bank run.

Finding the optimal r_1

- The bank chooses r_1 to maximize the expected utility of agents:

$$\lim_{\varepsilon\to 0} EU(r_1) = \int_0^{\theta^*(r_1)} \frac{1}{r_1} u(r_1) d\theta$$

$$+ \int_{\theta^*(r_1)}^{1} \lambda u(r_1) + (1-\lambda) p(\theta) u\left(\frac{(1-\lambda r_1)}{1-\lambda} R\right) d\theta$$

- Now, the bank has to consider the effect that an increase in r_1 has on risk sharing and on the expected costs of bank runs.

- Main question: Are demand deposit contracts still desirable?

- Result: If $\underline{\theta}(1)$ is not too large, the optimal r_1 must be larger than 1.
- Increasing r_1 slightly above 1 generates one benefit and two costs:
  - **Benefit:** Risk sharing among agents.
    - Benefit is of first-order significance: Gains from risk sharing are maximal at r_1=1.
  - **Cost I:** Increase in the probability of bank runs beyond $\underline{\theta}(1)$.
    - Cost is of second order: Liquidation at $\underline{\theta}(1)$ is almost harmless.

- **Cost II:** Increase in the welfare loss resulting from bank runs below $\underline{\theta}(1)$.
  - Cost is small when $\underline{\theta}(1)$ is not too large.

- Hence, the optimal r_1 generates panic-based bank runs.
- But, the optimal r_1 is lower than c_1^{FB}.
  - Hence, the demand-deposit contract leaves some unexploited benefits of risk sharing in order to reduce fragility.
  - To see this, let us inspect the first order condition for r_1:

$$\lambda \int_{\theta^*(r_1)}^{1} u'(r_1) - p(\theta) R u'\left(\frac{(1-\lambda r_1)}{1-\lambda} R\right) d\theta =$$

$$\frac{\partial \theta^*(r_1)}{\partial r_1}\left(\lambda u(r_1) + (1-\lambda) p\big(\theta^*(r_1)\big) u\left(\frac{(1-\lambda r_1)}{1-\lambda} R\right) - \frac{1}{r_1} u(r_1)\right)$$

$$+ \int_{0}^{\theta^*(r_1)} \frac{u(r_1) - r_1 u'(r_1)}{r_1^2} d\theta$$

- LHS: marginal benefit from risk sharing. RHS: marginal cost of bank runs.
- Since marginal cost of bank runs is positive, and since marginal benefit is decreasing in r_1: The optimal r_1 is lower than c_1^{FB}.

Policy Analysis: Optimal Deposit Insurance (Allen, Carletti, Goldstein, Leonello, 2015)

- In Diamond-Dybvig, deposit insurance eliminates runs and restores full efficiency.
  - It solves depositors' coordination failure without entailing any disbursement for the government.
- However, reality is more complex:
  - Runs also occur because of a deterioration of banks fundamentals and may do so even with deposit insurance.

- Design of the guarantee is crucial: should depositors be protected only against illiquidity due to coordination failures or also against bank insolvency?
- Guarantees may alleviate crises inefficiencies, but might distort banks' risk taking decisions.
- What is the optimal amount of guarantees taking all this into account?

- Notoriously rich and hard to solve model:
  - Endogenize the probability of a run on banks to see how it is affected by banks' risk choices and government guarantees.

- Endogenize banks’ risk choices to see how they are affected by government guarantees, taking into account investors expected run behavior

- We build on Goldstein and Pauzner (2005), where
  - Depositors’ withdrawal decisions are uniquely determined using the global-game methodology.
  - The run probability depends on the banking contract (i.e., amount promised to early withdrawers), and the bank decides on it taking into account its effect on the probability of a run.

- We add a government to this model to study how the government's guarantees policy interacts with the banking contract - our measure of risk- and the probability of a run.
- Some results:
  - o Guarantees can increase the probability of crises (via effect on banks' decisions), but still increase welfare.
  - o Programs that protect against fundamentals failures may be better than programs protecting only against panics.
  - o Distortions in risk taking can go the opposite way of what is typically expected.

Empirical Analysis: Complementarities and Fragility in the Data (Chen, Goldstein, and Jiang, 2010)

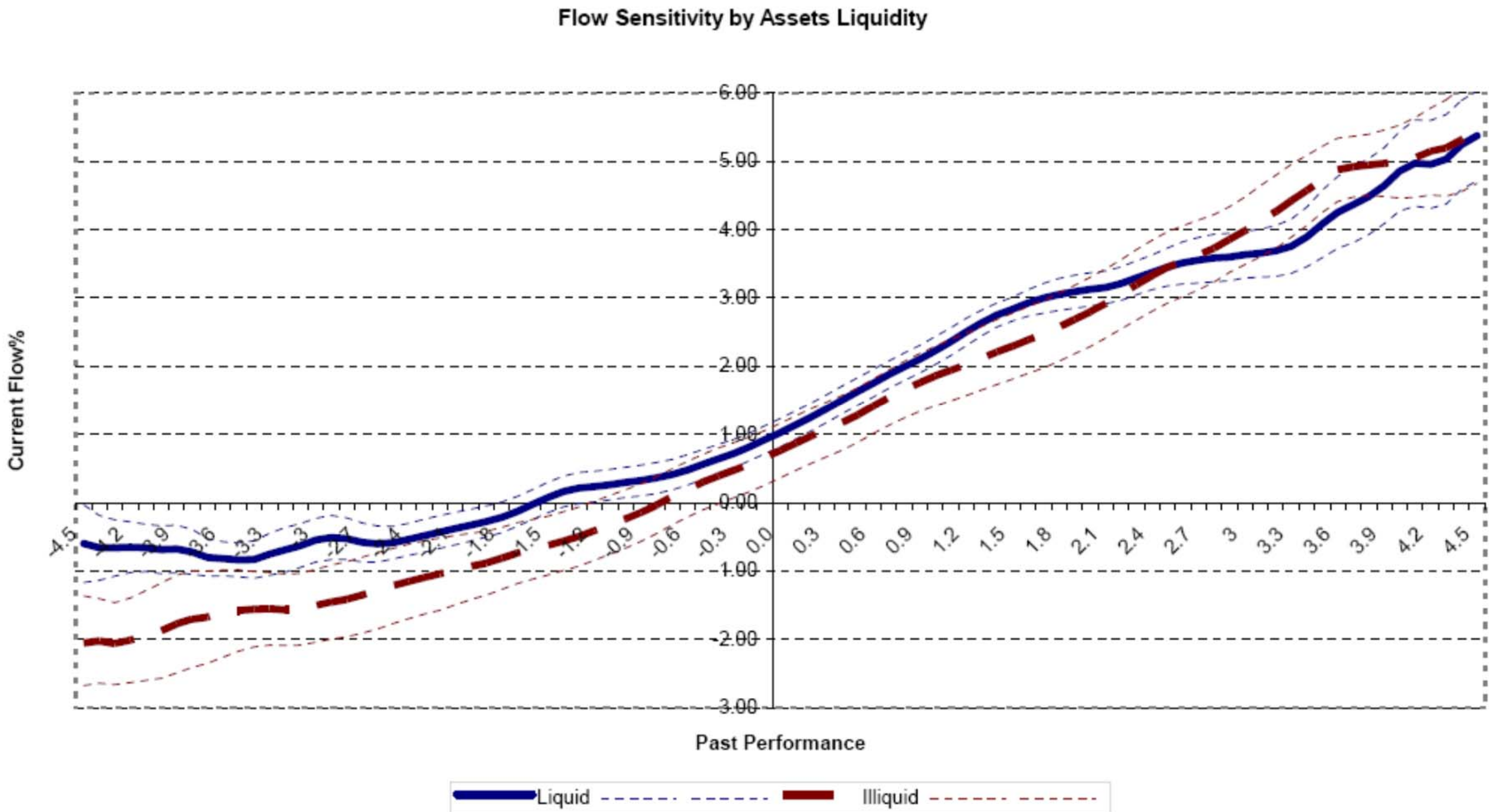
- Ample empirical evidence link crises to weak fundamentals.
- However, as demonstrated by the theoretical framework above, this does not say much about whether or not coordination failures and strategic complementarities play a role.
  - Even when coordination failures are involved, crises are more likely to occur at low fundamentals.
- Using mutual-fund data, we present an empirical test that relies on **cross-sectional differences in level of complementarities.**

Institutional Background

- In mutual funds, investors can redeem shares every day at last market value.
- Redemptions lead funds to trade later to rebalance the portfolio.
- If the fund holds illiquid assets, this will generate costs that will be imposed on the investors who stay in the fund.
- Hence, in mutual funds that hold illiquid assets (illiquid funds), there are strategic complementarities in the redemption decision, more so than in funds that hold liquid assets (liquid funds).

Hypotheses

- Using a global-games models, we develop the following predictions:
  - Illiquid funds exhibit stronger sensitivity of outflow to bad performance than liquid funds.
    - Complementarities amplify response to fundamental shocks.
  - This pattern will be weaker in funds that are held mostly by large/institutional investors.
    - These investors can better internalize the externalities, and thus respond less to complementarities.
- Hypotheses are confirmed in data and other explanations are refuted.


Flow Sensitivity by Assets Liquidity
Current Flow%
Past Performance
6.00
5.00
4.00
3.00
2.00
1.00
0.00
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-2.00
-3.00
-4.5
-4.2
-3.9
-3.6
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-3
-2.7
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Liquid
Illiquid

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