Contagious Bank Runs and Dealer of Last Resort

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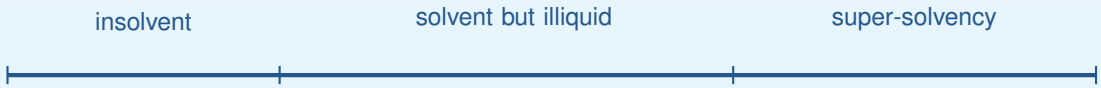
Bank Runs and the Traditional LoLR Policy

- Banks' liquidity mismatch and risk
- Central bank's role as Lender of Last Resort (LoLR)
- The classic LoLR according to Bagehot's principles
  - lend only to illiquid but solvent banks;
  - lend at a penalty rate;
  - lend against good collateral valued at pre-panic prices;
  - make clear in advance the readiness to lend any amount to any institution that meets the conditions for solvency and collateral.
- Theory underpinning: Solvent but illiquid banks as in global games.
- Rochet and Vives (2004)



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Forms of Federal Reserve Lending

	Regular OMOs	Discount Window[1]	Term Discount Window Program (announced August 17, 2007)	Term Auction Facility (announced December 12, 2007)	Primary Dealer Credit Facility (announced March 16, 2008)[2]	Transitional Credit Extensions (announced September 21, 2008)	Reciprocal Currency Arrangements (first announced December 12, 2007)[3]	Securities Lending	Term Securities Lending Facility (announced March 11, 2008)[2]	ABCP Money Market Fund Liquidity Facility (announced September 19, 2008)[2]	Commercial Paper Funding Facility (announced October 7, 2008)[2]	Money Market Investing Funding Facility (announced October 21, 2008)[4]	Term Asset-Backed Securities Loan Facility[5] (announced November 25, 2008)
Who can participate?	Primary dealers	Depository institutions	Primary credit-eligible depository institutions	Primary credit-eligible depository institutions	Primary dealers	U.S. and London broker-dealer subsidiaries of Goldman Sachs, Morgan Stanley, Merrill Lynch	Select central banks to lend on to banks in their jurisdiction[3]	Primary dealers	Primary dealers	Despository institutions, bank holding companies, U.S. branches and agencies of foreign banks	Eligible CP issuers[6]	Eligible Money Market Mutual Funds and other money market investors[7,8]	All U.S. persons that own eligible collateral
What are they borrowing?	Funds	Funds	Funds	Funds	Funds	Funds	U.S. Dollars	U.S. Treasuries	U.S. Treasuries	Funds	Funds	Funds and subordinated note	Funds
What collateral can be pledged?	U.S. Treasuries, agencies, agency MBS[9]	Full range of Discount Window collateral	Full range of Discount Window collateral	Full range of Discount Window collateral	Full range of tri-party repo system collateral[10,11]	Full range of Discount Window collateral and tri-party repo system collateral[11]	Central banks pledge foreign currency and lend against eligible collateral in their jurisdiction	U.S. Treasuries	U.S. Treasuries, agencies, agency MBS, and all invesment grade debt securities[10]	First-tier ABCP	Newly issued 3-month unsecured and asset-backed CP from eligible U.S. issuers	U.S. dollar-denominated certificates of deposit, bank notes and commercial paper issued by highly rated financial institutions	Recently originated U.S. dollar-denominated AAA ABS, CMBS and legacy CMBS[12,13]
Is there a reserve impact?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No (loans are bond-for-bond)	No (loans are bond-for-bond)	Yes	Yes	Yes	Yes
What is the term of loan?	Typically, term is overnight–14 days[14]	Typically overnight, but up to several weeks[16]	Up to 90 days[17]	28 days or 84 days[15]	Overnight	Overnight	Overnight to 3 months	Overnight	28 days[15]	ABCP maturity date (270-day maximum)	3 months	N/A	3 or 5 years
Is prepayment allowed if term is greater than overnight?	No	Yes	Yes	No	N/A	N/A	Yes	N/A	No	No	N/A	N/A	Yes
Which Reserve Banks conduct operations?	FRBNY	All	All	All	FRBNY	FRBNY	FRBNY	FRBNY	FRBNY	FRB Boston	FRBNY	FRBNY	FRBNY
How frequently is the program accessed?	Typically once or more daily	As requested (standing facility)	As requested (standing facility)	Every other week, or as necessary	As requested (standing facility)	As requested (standing facility)	Typically on schedule with FRBNY TAF auctions or as requested by central banks	Daily	Every four weeks	As requested (standing facility)	As requested (standing facility)	As requested (standing facility)	Twice a month, alternating between non-mortgage backed ABS and CMBS collateral types
Where are statistics reported publicly?	Temporary OMO activity[18]	H.4.1 - Factors Affecting Reserve Balances[19]	H.4.1 - Factors Affecting Reserve Balances[19]	TAF activity[18]	H.4.1 - Factors Affecting Reserve Balances[19]	H.4.1 - Factors Affecting Reserve Balances[19]	H.4.1 - Factors Affecting Reserve Balances[19]	Securities lending activity	Term securities lending facility activity[18]	H.4.1 - Factors Affecting Reserve Balances[19]	H.4.1 - Factors Affecting Reserve Balances[19]	H.4.1 - Factors Affecting Reserve Balances[19]	TALF activity[18]

[1] Discount Window includes primary, secondary and seasonal credit programs.

[2] The AMLF, CPFF, PDCF and TSLF will remain in operation through February 1, 2010 as announced on June 25, 2009.

[3] ECB and SNB announced December 12, 2007; BOC, BOE, and BOJ announced September 18, 2008; RBA, Sverige Riksbank, DNB, and Norges Bank announced September 24, 2008; Reserve Bank of New Zealand announced October 28, 2008; Banco Central do Brazil, Banco de Mexico, Bank of Korea, and Monetary Authority of Singapore announced October 29, 2008.

[4] The MMIFF will remain in operation through October 30, 2009 as announced on June 25, 2009.

[5] The Federal Reserve Board is prepared to increase the size of the TALF to as much as $1 trillion and broaden the eligible collateral to encompass other types of newly issued AAA-rated asset-backed securities as announced on February 10, 2009.

[6] Through the CPFF the FRBNY provides financing to an SPV that purchases eligible three-month unsecured and asset-backed commercial paper from eligible issuers.

[7] Eligible institutions expanded on January 7, 2009 to include U.S.-based securities-lending cash-collateral reinvestment funds, portfolios, and accounts (securities lenders); and U.S.-based investment funds that operate in a manner similar to money market mutual funds, such as certain local government investment pools, common trust funds, and collective investment funds

[8] Through the MMIFF the FRBNY will provide senior secured funding to a series of private sector SPVs to finance the purchase of certain money market instruments from eligible investors.

[9] Reverse repos are collateralized with U.S. Treasuries.

[10] PDCF and TSLF collateral expanded on September 14, 2008.

[11] Includes non-U.S. dollar denominated securities.

[12] Includes auto loans, student loans, credit card loans, small business loans guaranteed by the U.S. SBA, mortgage servicing advances, business equipment related loans or leases, vehicle fleet leases, floorplan loans and commercial mortgages. Collateral was expanded on March 19, 2009, May 1, 2009 and May 19, 2009.

[13] Legacy CMBS includes to U.S. dollar-denominated CMBS issued before January 1, 2009.

[14] Open market operations are authorized for terms of up to 65 business days.

[15] 28-day and 84-day terms may vary slightly to account for maturity dates that fall on Bank holidays.

[16] Primary credit loans are generally overnight. Loans may be granted for term beyond a few weeks to small banks, subject to additional administration.

[17] Maximum maturity of term increased from overnight to 30 days on August 17, 2007, and to 90 days on March 16, 2008.

[18] Data only available for days when operations are conducted.

[19] Data published on Thursday, as of close of business on Wednesday.

Deviation from the Traditional LoLR

- As argued by P. Mehrling (2010)
  - "...In the modern financial system, the fundamental role of the central bank is not so much Lender of Last Resort as Bagehot told us, as it is Dealer of Last Resort..."
- Three stages of Fed's intervention during 07-09 crisis as narrated by Mehrling
  - before the fall of Bear Sterns, just lowered the FFR from 5% to 2%
  - after that, behaved more aggressively by selling $500 billion treasury bills and lending the proceed to the broker dealers
  - after the Lehman Brothers and AIG's fall, started to intervene in the capital market itself, to expand the its balance sheet to purchase MBS, and eventually 'became the interbank market'.
- Fed became the dealer of (risky) assets
  - provided liquidity to the asset market
  - kept a 'floor' to the financial system
  - took on credit risk as compared to the traditional LoLR
- Similar features for ECB's LTRO and OMT

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What do we do in this paper?

- Highlight the information constraints in central bank Emergency Liquidity Assistance (ELA) programs.
- Characterize the defining features of recent ELA programs, as represented by the so-called DoLR policies.
- Provide a micro-founded explanation why the DoLR policies can outperform traditional LoLR policies.

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Overview: Information Friction and Twin Illiquidity

- Information Constraints
  - fundamental runs indistinguishable from coordination failures
  - the info constraint applies both to central banks and private parties
- The info constraint both creates financial fragility and restrict ELA policies.
- Financial fragility: two-way feedback between runs and falling asset prices
  - to study ELAs, our starting point has to be a financial fragility model
    - suppose creditors panic and run on a solvent bank
    - the bank forced into early liquidation, pooled with the insolvent
    - such information asymmetry leads to a low price the bank's asset
    - the low price justifies the run in the first place
- For central banks: Difficult to carry out LoLR policies as suggested by Bagehot

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Aggregate Uncertainty, Multiple Equilibria, and Policy Intervention

- The two-way feedback + Aggregate uncertainty $\Rightarrow$ Financial Fragility
  - aggregate uncertainty: banks' exposure to systematic risks
  - contagion through asset prices & information externalities
    - the observation of a run $\Rightarrow$ pessimistic belief about the common risk
    - lower willingness to pay $\Rightarrow$ precipitates contagious runs at other banks
- Financial fragility can emerge as a multiple-equilibria phenomenon
  - for the same fundamental, multiple equilibrium outcomes are possible
  - interpreted as financial contagion and price volatility
  - global-games approach no longer guarantees uniqueness
  - coordination on the belief about the systematic risk
- The existence of multiple equilibria also creates scope for policy intervention.

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Policy Implications: the Stability Effects of DoLR

- DoLR policies can break down the vicious cycle.
  - a regulator can reduce financial stability with no better information
  - achieving so by making a stand-by offer for bank assets
    - so, the policy targeting at (strategic) asset
    - not conditional on individual banks' solvency/liquidity position
  - pre-emptive: price offered before the realization of aggregate uncertainty
  - backstop price according to the prior (long-run fundamental)
- We show DoLR can eliminate the 'bad' equilibria while keep the 'good' ones.
- Private market vs. DoLR intervention
  - market price can be (to some extent) belief-driven
  - the regulator should stick to the long-run fundamental
  - the importance of commitment power
  - disengage the feedback between falling asset prices and runs

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LoLR, DoLR and ELA in General

- A comparison between Traditional LoLR and DoLR

	Lender of Last Resort (LoLR)	**Dealer of Last Resort (DoLR)**
Direct target	Individual financial institutions	(Strategic) bank assets
Policy channels	Funding liquidity	Market liquidity
Eligible collateral	'Good' collateral	A wide range of collateral
Credit risk for CB	No	Possible
Duration	Term of loan typically overnight, up to a few weeks	Up to years, indefinitive in the case of asset purchase
Information required	Info on individual FIs' solvency	Valuation of securities to purchase
Timing	Ex-ante/ex-post intervention	Ex-ante intervention
Policy objective	Avoiding inefficient liquidation of individual FIs	Preventing systemic meltdowns

- Why DoLR policies can be more effective than the traditional LoLR?
  - less information demanding
  - policy objective
- We further examine, more broadly, how Emergence Liquidity Assistance (ELA) policies should be designed given information constraints.
  - the availability of info to the regulators
  - how costly it is to communicate the info to the public

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The Literature on Bank Runs and ELA

- ELA: Bagehot (1873) $\Rightarrow$ Rochet and Vives (2004) $\Rightarrow$ Mehrling (2010, 2012)
- We formalize DoLR in a global-games framework
- Panic-based bank runs: multiple equilibria, sun-spot bank runs
  - Diamond-Dybvig (1983)
- Refinement by global games: unique (threshold) equilibrium
  - Morris & Shin (2000), Rochet & Vives (2004), Goldstein & Pauzner (2005)
  - unique equilibrium, cut-off fundamental, solvent but illiquid banks
  - empirical evidence: Gorton (1988), Calomiris & Gorton (1991), etc.
- Some limitation: simplifying assumption of exogenous fire-sale prices/losses
  - omitting the reinforcing effect of bank runs on asset fire sales
  - full determinacy of standard global games does not allow fragility
- Our contribution to the bank run literature
  - endogenizing asset prices based on information friction
  - generalization with aggregate uncertainty, multiple banks, and systemic risk

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The Global Games Literature

- Refinement and unique equilibrium: first application: Morris & Shin (1998)
  - bank runs: Rochet & Vives (2004), Goldstein & Pauzner (2005)
- When can multiple equilibria resurface?
  - Signaling (policy trap)
    - Angeletos et. al. (2006), Angeletos & Pavan (2013)
  - Repeated attack and learning
    - Angeletos et. al. (2007)
  - Agents coordinate on the public signal of asset prices
    - Angeletos & Werning (2006), Ozdenoren & Yuan (2008)
    - fragility takes the form of excessive asset price volatility
- Our contribution is most related to the last strand of the literature
  - a two-dimensional setup: idiosyncratic vs. systematic risk
  - fragility takes the form of systemic bank failures unrelated to fundamentals
  - one step beyond: how to eliminate 'bad' equilibria

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Model Setup

Banks, their Assets and Liabilities

- Ex ante identical banks, indexed by $j = 1, 2, 3, ..., N$
- Three dates: $t = 0, 1, 2$
- Assets: 1 unit long-term risky portfolio, unit size, maturing at $t = 2$
  - each individual bank generates a cash flow $\tilde{\theta}^j \sim U(\underline{\theta}_s, \overline{\theta})$
  - aggregate states $s \in \{G, B\}$, with $\underline{\theta}_B < \underline{\theta}_G$
  - prior beliefs: $Prob(s = G) = \alpha$, historical perspective
  - $\theta \Leftrightarrow$ idiosyncratic risk, $s \Leftrightarrow$ systematic risk
- Liabilities: financed by equity E, deposits F and short-term debts $1 - E - F$
  - deposits: fully insured, risk-free rate normalized to 1
  - short-term debts: demandable and risky
    - gross interest rate r_D at $t = 2$, and qr_D at $t = 1$
    - $D_1 = (1 - E - F)qr_D$
    - $D_2 = (1 - E - F)r_D + F$
- Banks are passive, forced into liquidation when runs occur

Parametric Assumptions and Bankruptcy Cost

- Risky banking
  - $D_2 > \underline{\theta}_s$
- Substantial use of retail/stable funding
  - $F > D_1$
- Moderate penalty for early withdrawals
  - $q > 1/2 + \underline{\theta}_G/2D_2$
  - consistent with banks' function of providing liquidity insurance
- We do not endogenize banks' capital structure.
  - as long as an optimal capital structure satisfies the assumptions,
  - $\Rightarrow$ all of our results will qualitatively hold.
- In case of bank failure
  - retail funding senior to wholesale funding
  - when residual value $< F$, deposit insurance fills the gap
  - bankruptcy cost $C \Rightarrow$ welfare implication

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Wholesale Creditors & Runs

- Creditors' coordination game refined by the global-games approach
- A continuum of creditors
  - holding the short-term demandable debt of all banks
  - two actions at each bank, 'withdraw' at $t = 1$ or 'wait' till $t = 2$
  - no common knowledge on banks' fundamentals
    - private signal $x_i^j = \theta^j + \epsilon_i^j$, for a creditor i at bank j
    - ϵ_i^j uniformly distributed on $[-\epsilon, \epsilon]$, ϵ arbitrarily small
    - ϵ_i^j independent across banks and individual creditors
- Creditors' payoffs depend on their action and the solvency of the bank
  - when the bank does not fail: qr_D from 'withdrawal', r_D from 'wait'
  - when the bank fails: zero payoff from 'wait', benefit $\to 0$ from 'withdrawal'
- Forward-looking creditors: form rational expectation of asset prices
- Focus on simultaneous moves and symmetric equilibrium

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Secondary Asset Market and Informational Friction

- Early liquidation $\Rightarrow$ assets sold to uninformed asset buyers
  - observe neither θ nor s
  - cannot distinguish the illiquid from the insolvent
  - can observe the number of bank runs M, $M \in \{1, 2, ..., N\}$
  - based on M, form rational beliefs about θ and State s
  - won't be called into move if no run happens
- Asset buyers offer a price schedule $\boldsymbol{P} = (P_1\ P_2\ ...\ P_N)$
  - purchasing assets for price P_M when observing M bank runs
  - price competition in the secondary asset market
  - in the equilibrium, buyers only break even
  - zero expected profit based on their posterior beliefs

DoLR Intervention

- Regulator intervenes by making a stand-by offer P_A.
  - P_A announced before the realization of s and $\boldsymbol{\theta}$
  - P_A independent of the number of runs
  - full commitment power assumed for simplicity
- The policy, despite its simple form, captures the main features of DoLR policies
  - targeting at asset not individual banks,
  - ex-ante intervention
  - allowing credit risk
  - not information demanding, long duration, etc.
- The regulator can make no expected loss.
- The policy intervention does not exclude private market.
  - only providing a back-stop on the asset price
  - no intervention when the market price higher than P_A
- We also discuss why this design and how to maintain the commitment power.

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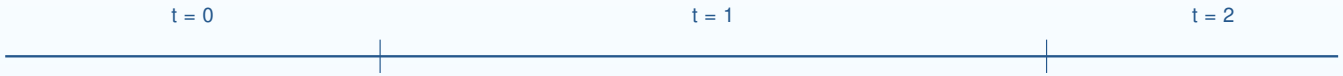
Timing of the Game

- Timing in a laissez-faire market

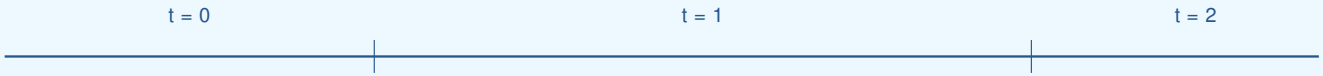


Banks are established, with their portfolios and liability structures as given.

1. s and $\boldsymbol{\theta}$ realize sequentially.
2. Creditors receive noisy private signals $\boldsymbol{x}$ about $\boldsymbol{\theta}$, and decide to run or not for each of the banks.
3. If any bank run occurs, buyers bid and purchase assets on sale according to the number of runs observed.

1. Returns become public.
2. Remaining obligations are settled.

- Timing under the DoLR policy



1. Banks are established, with their portfolios and liability structures as given.
2. *A regulator announces its commitment to buy bank assets for a unified price P_A, if any bank run happens.*

1. s and $\boldsymbol{\theta}$ realize sequentially.
2. Creditors receive noisy private signals $\boldsymbol{x}$ about $\boldsymbol{\theta}$, and decide to run or not for each of the banks.
3. If any bank run occurs, buyers bid for assets on sale according to the number of runs observed, and *acquire the asset only if their bids are higher than P_A.*

1. Returns become public.
2. Remaining obligations are settled.

Market Equilibrium

The Equilibrium Concept and Solution

- Equilibrium concept: PBE
- A market equilibrium $(x^*, \boldsymbol{P})$, $\boldsymbol{P} = (P_1^* P_2^* ... P_N^*)$
  - creditors play a bank run game
    - form beliefs about fundamentals $\boldsymbol{\theta}$ and other creditors' actions
    - switching threshold x^* and associated critical fundamental θ^*
  - uninformed asset buyers bid competitively when bank assets are on sale
    - forming rational beliefs about $\boldsymbol{\theta}$ and s
    - offering P_M when observing M bank runs
  - x^* and $\boldsymbol{P}$ are sequentially rational, given the beliefs
- Fundamental + Equilibrium strategies $\Rightarrow$ Equilibrium outcome(s) (P_M^*, M)
- The procedure to solve for an equilibrium
  1. solve asset buyers' best response $\mathbb{P}_M(\theta^*)$
  2. solve the bank run game for θ^* with forward-looking price $\mathbb{P}_M(\theta^*)$
  3. equilibrium pinned down as a fixed point

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Secondary Asset Market

- If the critical cash flow is θ^*, what would be the asset price?
- Beliefs about $\boldsymbol{\theta}$: $\theta < \theta^*$, conditional on the observation of liquidation
- Beliefs about s:

$$\omega_M^B(\theta^*) \equiv Prob(s = B|\theta < \theta^*, M) = \frac{\left(\theta^* - \underline{\theta}_B\right)^M}{\left(\theta^* - \underline{\theta}_B\right)^M + \kappa\left(\theta^* - \underline{\theta}_G\right)^M}$$

$$\omega_M^G(\theta^*) \equiv Prob(s = G|\theta < \theta^*, M) = \frac{\kappa\left(\theta^* - \underline{\theta}_G\right)^M}{\left(\theta^* - \underline{\theta}_B\right)^M + \kappa\left(\theta^* - \underline{\theta}_G\right)^M},$$

where $\kappa = \kappa \equiv \frac{\alpha}{1-\alpha}\left(\frac{\overline{\theta} - \underline{\theta}_B}{\overline{\theta} - \underline{\theta}_G}\right)^N$.

- Equilibrium of competitive bidding requires

$$\mathbb{P}_M(\theta^*) = E\left[\theta\middle|\theta < \theta^*, M\right] = \omega_M^B(\theta^*)\frac{\underline{\theta}_B + \theta^*}{2} + \omega_M^G(\theta^*)\frac{\underline{\theta}_G + \theta^*}{2} \quad (1)$$

  - Creditors' strategy affects $\mathbb{P}_M(\theta^*)$ in two ways.
- Price bounded: $\mathbb{P}_M(\theta^*) \in [\underline{P}, qD_2)$, with $\underline{P} = \frac{\underline{\theta}_B + D_2}{2}$.
  - implication: no bank failure at $t = 1$
  - relationship to the parametric assumption $q > 1/2 + \theta_G/2D_2$

Bank Runs and the Equilibrium of the Game

- Expecting $\mathbb{P}_M(\theta^*)$, what would be the equilibrium of the bank run game?
- Solve for symmetric threshold equilibrium (x^*, θ^*)
  - Upper and lower dominance regions $\left[\underline{\theta}_s, \theta^L\right)$ and $\left(\theta^U(\mathbb{P}_M), \overline{\theta}\right]$ exist.
  - Suppose all other creditors taking a threshold strategy characterized by x^*. Creditor j' best response is also a threshold strategy, characterized by $\hat{x}$.
  - The symmetric equilibrium obtains when $\hat{x} = x^*$, the only equilibrium that survives iterated elimination of strictly dominated strategies.
  - x^* and θ^* are pinned down by the indifference condition of the critical creditor who observes x^*, and the regime switching condition for the bank whose fundamental is θ^*. In the limiting case, $x^* = \theta^*$.

$$\theta^* = \frac{D_2 - D_1}{1 - qD_1/\mathbb{P}_M(\theta^*)} \tag{2}$$

- An equilibrium of the game, if exists, must satisfy equation (2).
- Fixed point equilibrium: We examine its existence and uniqueness.

Unique Equilibrium w/o Aggregate Uncertainty

- A baseline model with only one state: $\underline{\theta}_B = \underline{\theta}_G = \underline{\theta}$
  - no contagion, nor belief updating about s
  - price reflecting only asymmetric information
- Equilibrium pinned down by

$$P^* = \frac{\underline{\theta} + \theta^*}{2} \quad \text{and} \quad \theta^* = \frac{D_2 - D_1}{1 - qD_1/P^*}$$

- Unique equilibrium: $P^* \in [\underline{P}, qD_2)$ and $\theta^* \in \left(\theta^L, \theta^U(P^*)\right)$
  - stable equilibrium
  - closed-form solutions can be obtained
  - inefficiency captured by $\theta^* - D_2$
- Unique equilibrium due to the unique belief on the $\underline{\theta}$
  - results not that different from classic global-games based bank run models
  - DoLR policies cannot improve stability, at least without incurring losses
  - the impossibility result serves as a benchmark

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Multiple Equilibria with Aggregate Uncertainty

- Introducing aggregate uncertainty $\underline{\theta}_B < \underline{\theta}_G$
- Posterior beliefs about s depend on the number of bank runs M.
- Equilibrium pinned down by

$$\mathbb{P}_M(\theta^*) = \omega_M^B(\theta^*)\frac{\underline{\theta}_B + \theta^*}{2} + \omega_M^G(\theta^*)\frac{\underline{\theta}_G + \theta^*}{2}$$

$$\theta^* = \frac{D_2 - D_1}{1 - qD_1/\mathbb{P}_M(\theta^*)}$$

- *For any given* M, a unique pair (θ_M^*, P_M^*) solves the equations.
- Ranking of the solutions
  - more runs observed $\Rightarrow$ pessimistic ex-post belief on s
  - for $M_1 < M_2 < N$, we have $\theta_{M_1}^* < \theta_{M_1}^*$ and $P_{M_1}^* > P_{M_2}^*$
- For certain fundamentals, creditors can form distinct beliefs about M.

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Multiple Equilibria with Aggregate Uncertainty (Cont'd)

- Multiple equilibria emerge for the same fundamental.
  - multiple equilibrium thresholds θ_M^*
  - equilibrium price schedule $\boldsymbol{P}^* = (P_1^* P_2^* ... P_N^*)$, with $P_M^* = \mathbb{P}_M(\theta_M^*)$
- Aggregate uncertainty $\Rightarrow$ global-games no longer guarantees uniqueness.
  - wholesale creditors aware of the price impact of their runs
  - pessimistic strategy (i.e., high θ_M^*) $\Rightarrow$ more bank runs (greater M) $\Rightarrow$ depressed asset prices (lower P_M^*) $\Rightarrow$ pessimistic strategy justified
  - coordination on the belief about the systematic risk s
  - different θ_M^* associated with different belief ω_M^B
- Multiple equilibrium $\Rightarrow$ Financial fragility
  - distinct equilibrium outcomes for the same fundamental
  - asset price volatility
  - financial contagion
- Substantial fragility: The multiple equilibria exist in, but not confined to, states where all banks' fundamental $\in (\theta_1^*, \theta_N^*]$.

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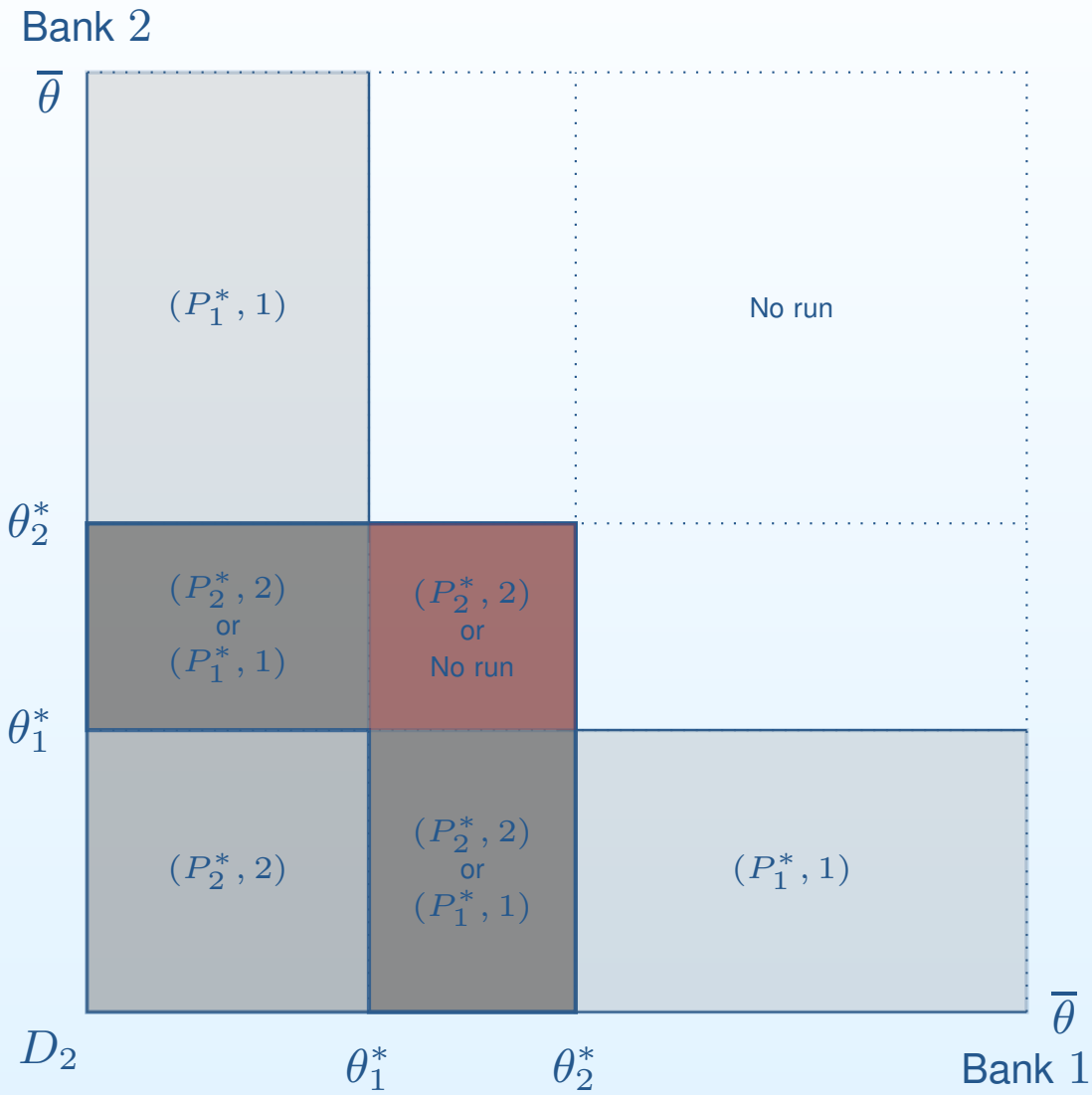
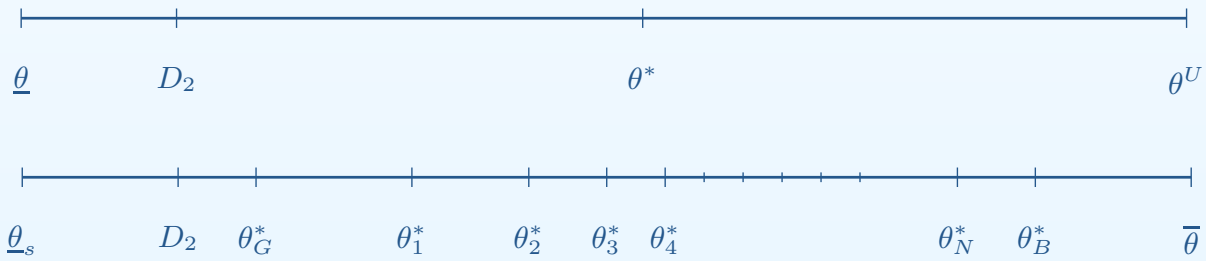
An Illustration with $N = 2$



General N-bank Case

- Each equilibrium associated with one belief on s
  - θ_B^* associated with belief $prob(s = B) = 1$
  - θ_G^* with belief $prob(s = B) = 0$
  - $\theta_G^* < \theta_1^* < \theta_2^* < ... < \theta_N^* < \theta_B^*$ associated with $\omega_M^B, M = 1, 2, ..., N$
  - As $N \to \infty$, $\theta_N^* \to \theta_B^*$. Extreme financial fragility can emerge.



- Generalization of bank run models à la Rochet and Vives
- A hybrid model of bank runs: runs both belief- and fundamental-driven.
  - no full determinacy as in classic global-games based models
  - while belief-driven runs (locally) exist, beliefs cannot be arbitrary

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Dealer of Last Resort

DoLR Intervention

- Can a regulator improve welfare, *even without better information*?
- Central banks as dealers of last resort
  - commitment to purchase assets at price P_A
  - announcing P_A (a stand-by offer) before the realization of s and θ
  - in particular, P_A does not vary with N
- A unique P_A^* allows the DoLR to break even from an ex-ante perspective.
  - eliminates 'bad' equilibria (those associated with $\omega_M^B > 1-\alpha$)
  - keeps 'good' equilibria (those associated with $\omega_M^B < 1-\alpha$)
  - $P_A^* > P_N^*$ always holds; $P_A^* > P_1^*$ if N small and (or) α big.
- To see the stability effects, consider two examples.
  - Example 1: the extreme fragility: all θ marginally below θ_N^*
  - equilibrium outcome (P_M^*, M) can no longer emerge.
  - Example 2: one bank's $\theta < \theta_1^*$; one and only one bank's $\theta \in [\theta_M^*, \theta_{M+1}^*)$
  - equilibrium outcome (P_M^*, M) where $P_M^* < P_A^*$ can no longer emerge.

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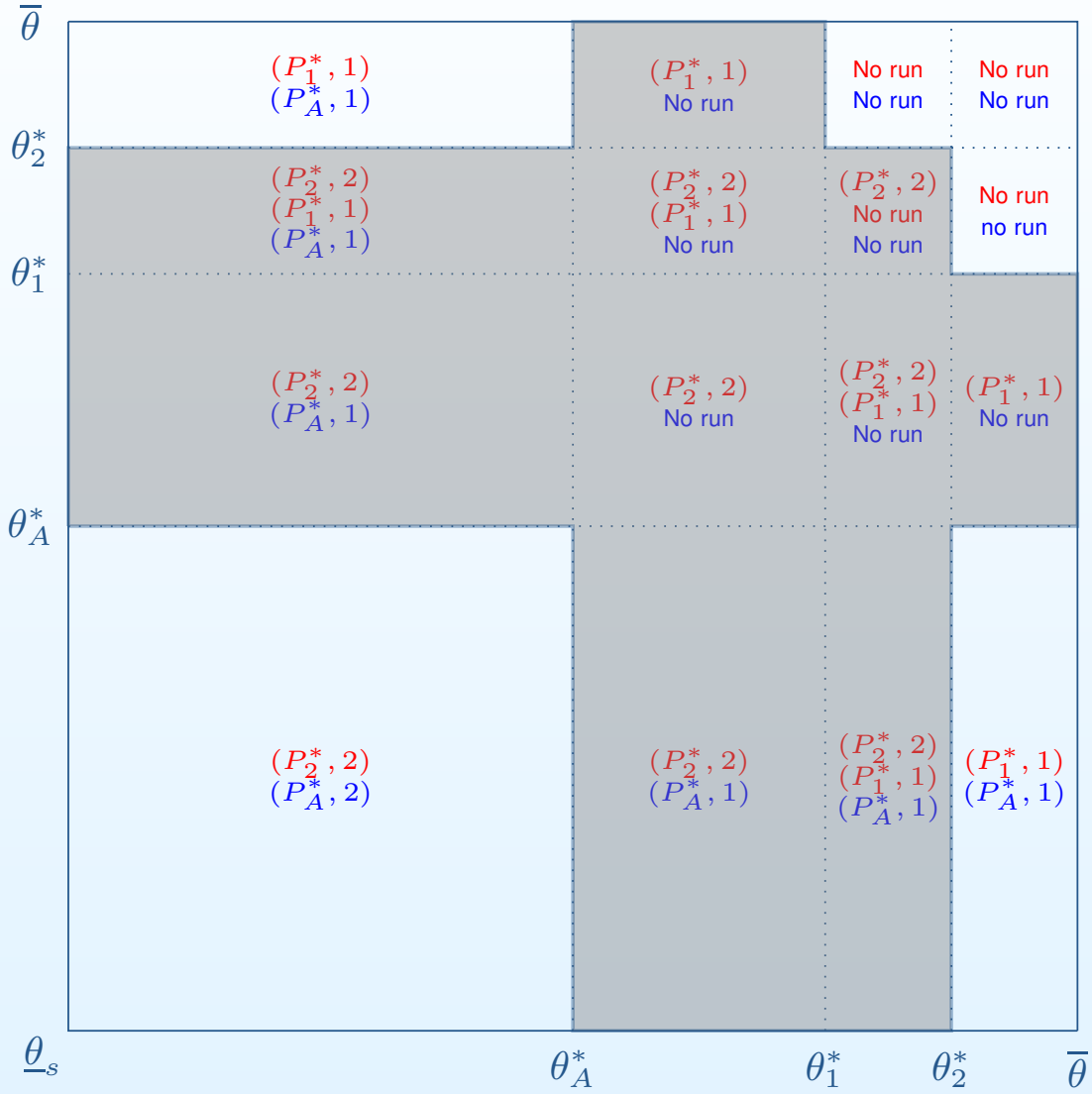
Further Illustration with $N = 2$ $(P_A^* > P_1^*)$



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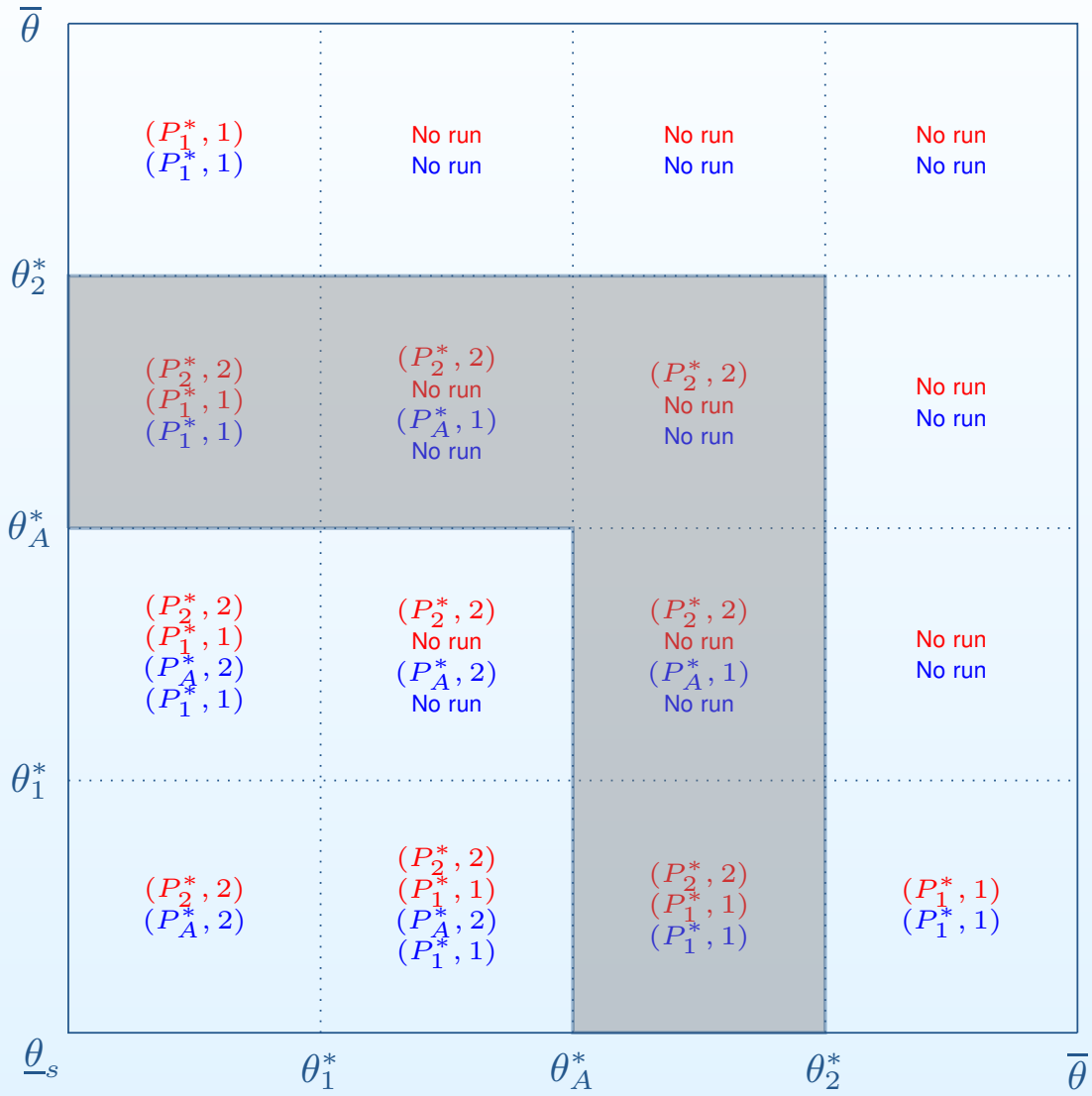

P_A^* vs. P_M^*: How Does the DoLR Policy Work?

- Private asset buyers
  - for each realised M, requiring to break even from an ex-post perspective
    - profits: banks with $\theta \in [P_M^*, \theta_M^*)$
    - losses: banks with $\theta \in [\underline{\theta}_s, P_M^*]$
    - setting low P_M^* to break even (root of financial fragility)
  - pricing in new information (the number of bank runs)
  - the number of runs M, however, is endogenous to buyers' belief
  - a pessimistic belief (high ω_M^B) $\Rightarrow$ lower P_M $\Rightarrow$ more runs $\Rightarrow$ belief justified
- The regulator in the asset purchase program
  - P_A^* announced before the realization of s and θ
  - allowing the regulator to break even from an ex-ante perspective
  - move surplus across states: profits in State G, and losses in State B
  - in terms of breaking even, relying less on the reduction of asset prices
- Problem with the market: a lack of commitment power

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Information Constraints and the Design of ELA Policies

- Can the regulator do better when knowing s?
  - option 1: setting price conditional on s
  - option 2: disclosing s
- Information on s does not necessarily help!

- More broadly, how should the availability of info affect the design of ELA?

	Perfect communication	Imperfect communication
θ	Traditional LoLR equivalent to disclosing θ	Traditional LoLR (disclosing θ can create a policy trap)
M	Cannot to improve over market outcome	
s	disclosure	separation: efficiency bounded by disclosure pooling: going back to M
No Info	DoLR as the only possible intervention	

- W/o info constraints, traditional LoLR works perfectly (alternative policies too).
- W/ info constraints, DoLR as modelled can be the best choice.

Further Discussion

- A few observations of the DoLR policy
  - reducing (though not eliminating) funding liquidity risk
  - does not always involve CB purchasing bank assets
- Sources of commitment power
  - more credibility due to different objective functions
  - reasons to establish stability fund
  - main results would hold, as long as central banks hold stronger commitment power than private parties
- Moral hazard problem under DoLR
  - policy makers do not only face information constraints
  - incentive compatible constraints also matter
  - moral hazard under traditional LoLR has been a concern
  - unlikely to create greater moral hazard compared to the traditional LoLR

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Conclusion

Concluding Remarks

- Theory framework: a bank run model with hybrid features
  - bank runs and fire sales mutually reinforce each other
  - the feedback driven by a lack of information
  - financial fragility as a multiple-equilibria phenomena
- Policy implication: the effectiveness of DoLR policies
  - formalizing the concepts with its defining features
  - promote stability at zero expected cost
  - restricting the set of multiple equilibria
  - the importance of commitment power
  - the design of ELA policies in the presence of info friction

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