Global Games and Financial Fragility:

Foundations and a Recent Application

Itay Goldstein

Wharton School, University of Pennsylvania

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: 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

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

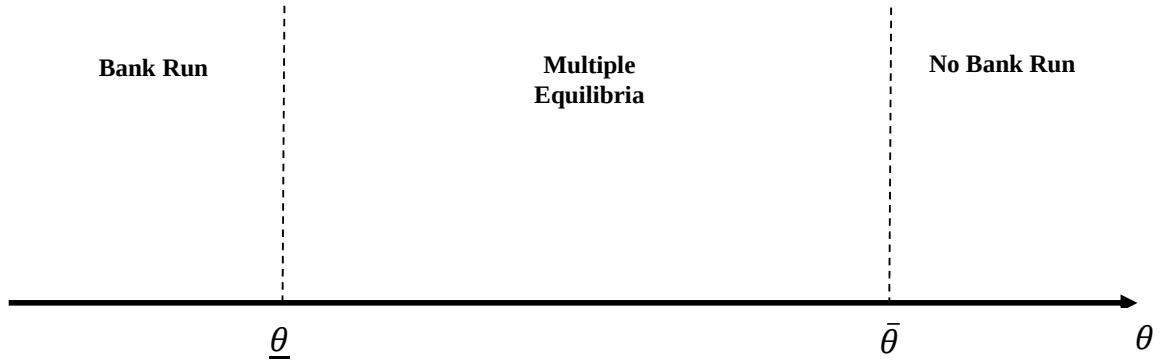
- **Empirical analysis:** what constitutes sufficient evidence for the relevance (or lack of) of strategic complementarities in fragility?
  - Large body of empirical research associates crises with weak fundamentals. Is this evidence against the panic-based approach?
  - How can we derive empirical 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)

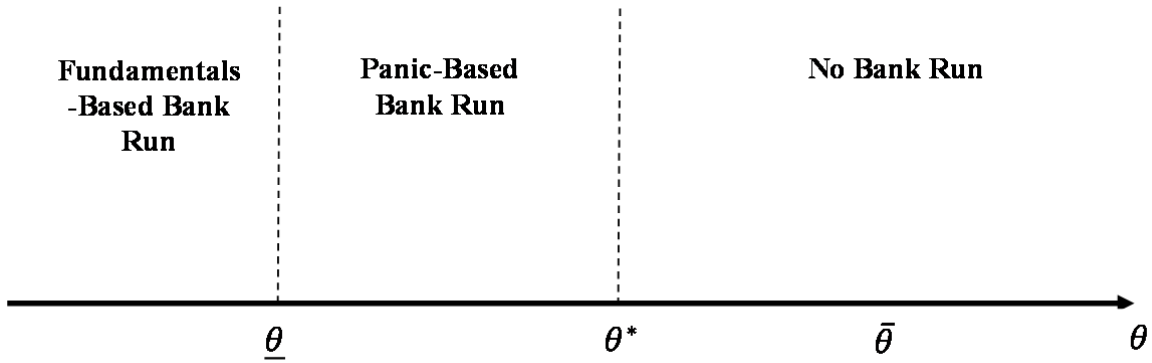
Equilibrium with Global Games: Step I

- 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

Working with Global-Games Equilibrium

- Run probability captured by threshold θ^*, 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

E. Carletti [†] I. Goldstein [‡] A. Leonello [*]

[†]Bocconi University and CEPR

[‡]University of Pennsylvania

[*]European Central Bank

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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?

▸ Regulation

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
  - ℓ is a choice variable capturing bank portfolio liquidity $\rightarrow$ liquidity/return trade-off
  - $\theta \sim U[0, 1]$, $R'(\theta) > 0$ and $0 < \alpha \leq \overline{\alpha}$ is cost of liquidity

The baseline model: debt holders' information

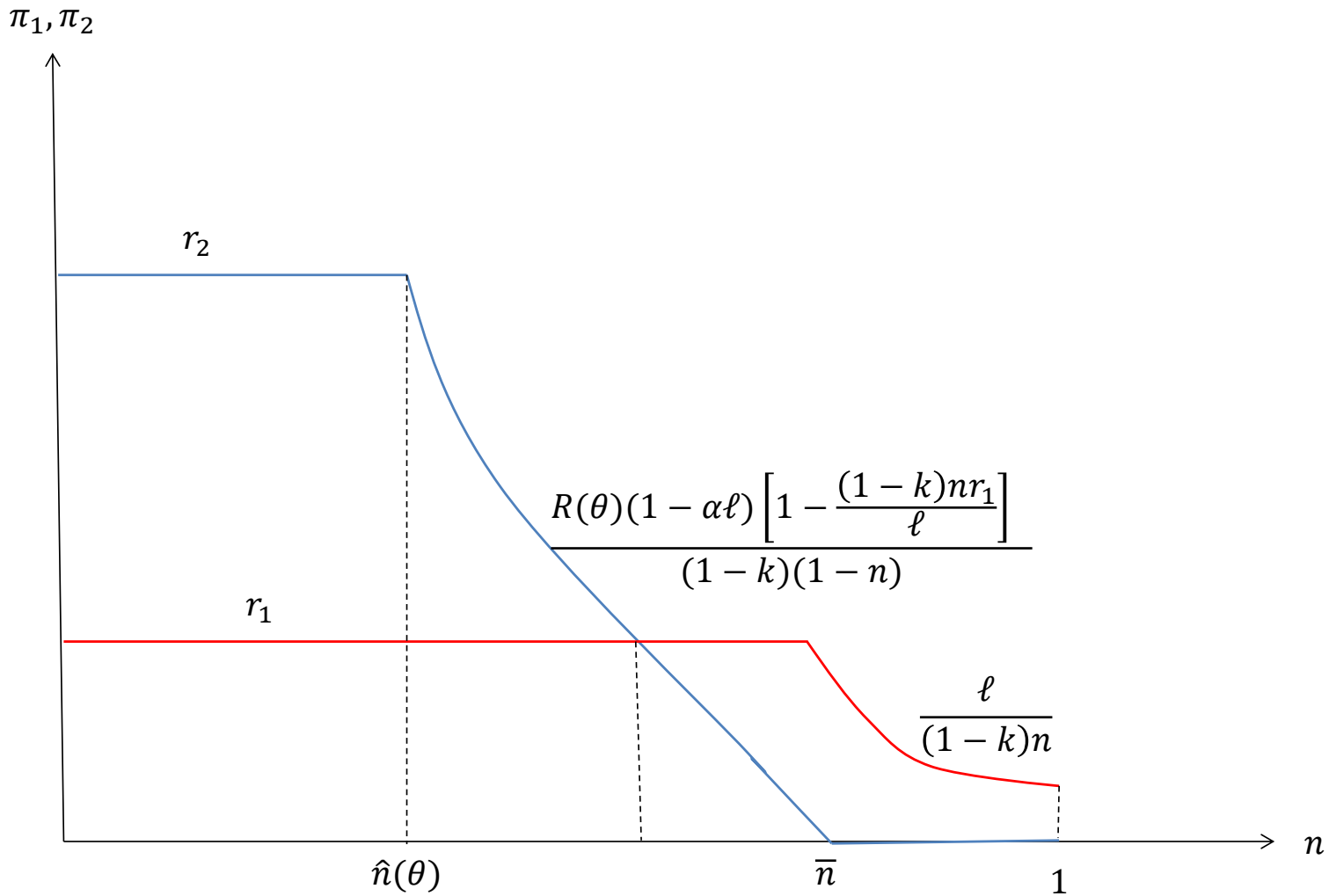
- At the beginning of date 1, each debt holder receives a private signal s_i on the fundamental of the economy of the form

$$s_i = \theta + \varepsilon_i$$

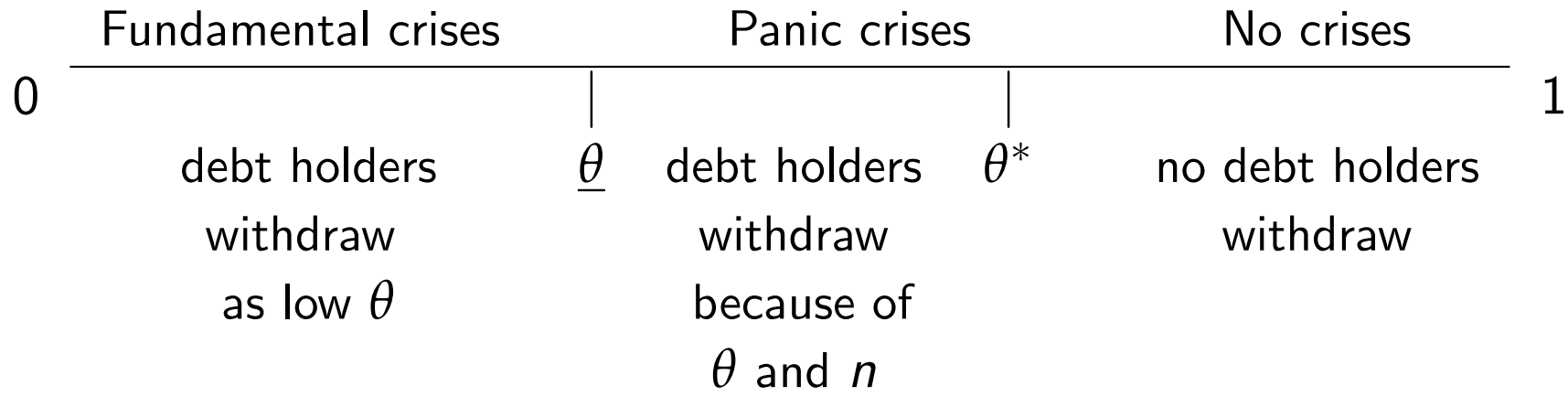
  with $\varepsilon_i \sim U[-\varepsilon, +\varepsilon]$ being i.i.d. across agents and $\varepsilon \to 0$
- Based on the signal, debt holders decide whether to withdraw (run) at date 1 or roll over their debt
  - They update their beliefs about θ and the others' actions
- The bank satisfies early withdrawals 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 θ and n matter (strategic complementarity)



Debt holders' rollover decision and crises



where $\underline{\theta}$ is the solution to

$$R(\theta)(1-\alpha\ell) = (1-k)\, r_1$$

and θ^* to

$$\int_{n=0}^{\widehat{n}(\theta)} r_2 + \int_{n=\widehat{n}(\theta)}^{\bar{n}} \frac{R(\theta)(1-\alpha\ell)\left[1-\frac{(1-k)nr_1}{\ell}\right]}{(1-k)(1-n)} = \int_{n=0}^{\bar{n}} r_1 + \int_{n=\bar{n}}^{1} \frac{\ell}{(1-k)\, n}$$

▸ Graphs

The effect of capital on crisis probability

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

$$\underbrace{-\int_{\widehat{n}(\theta)}^{\overline{n}} \frac{R(\theta)(1-\alpha\ell)}{(1-k)(1-n)}dn}_{\text{Higher repayment at date 2}} \underbrace{+\int_{\overline{n}}^{1} \frac{\ell}{(1-k)n}dn}_{\text{Higher repayment at date 1}}$$

- Initial balance sheet composition (i.e., k and ℓ) determines which effect dominates

The effect of liquidity on crisis probability

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

$$\underbrace{-\int_{\widehat{n}(\theta)}^{\overline{n}} \frac{R(\theta)\, n r_1}{\ell^2 (1-n)} dn}_{\text{Higher repayment at date 2 due to less liquidation at date 1}} + \underbrace{\int_{\widehat{n}(\theta)}^{\overline{n}} \frac{\alpha R(\theta)}{(1-k)(1-n)} dn}_{\text{Lower repayment at date 2 due to lower profitability}} \underbrace{+ \int_{\overline{n}}^{1} \frac{1}{(1-k)\, n} dn}_{\text{Higher repayment at date 1}}$$

- Again, initial balance sheet composition (i.e., k and ℓ) determines which effect dominates

The bank's choice

- Given debt holders' rollover decisions, at date 0 each bank chooses k, ℓ and r_2 to maximize

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

subject to

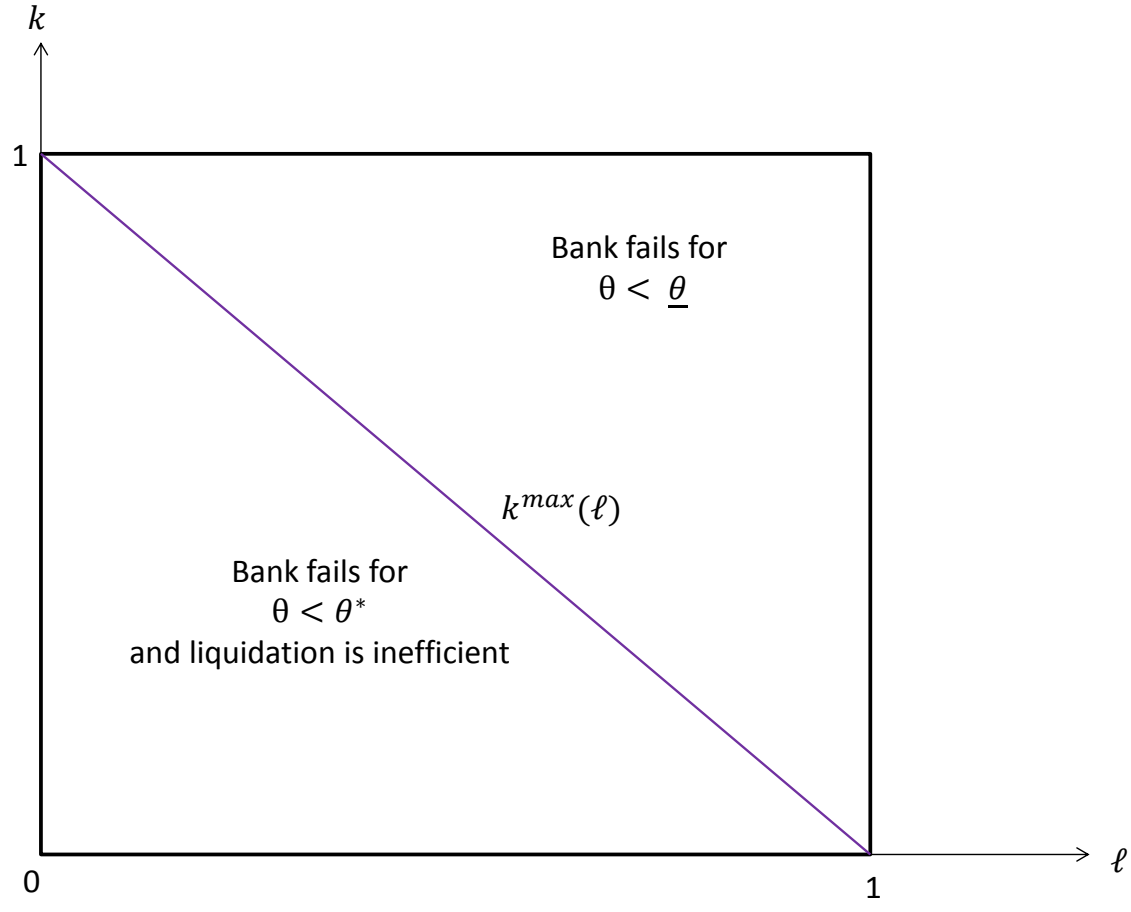
$$\int_0^{\theta^*} \frac{\ell}{\left(1-k\right)} d\theta + \int_{\theta^*}^{1} r_2 d\theta \geq 1 \text{ and } \Pi^B \geq 0$$

- The choice of (k, ℓ) 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

▸ FOC

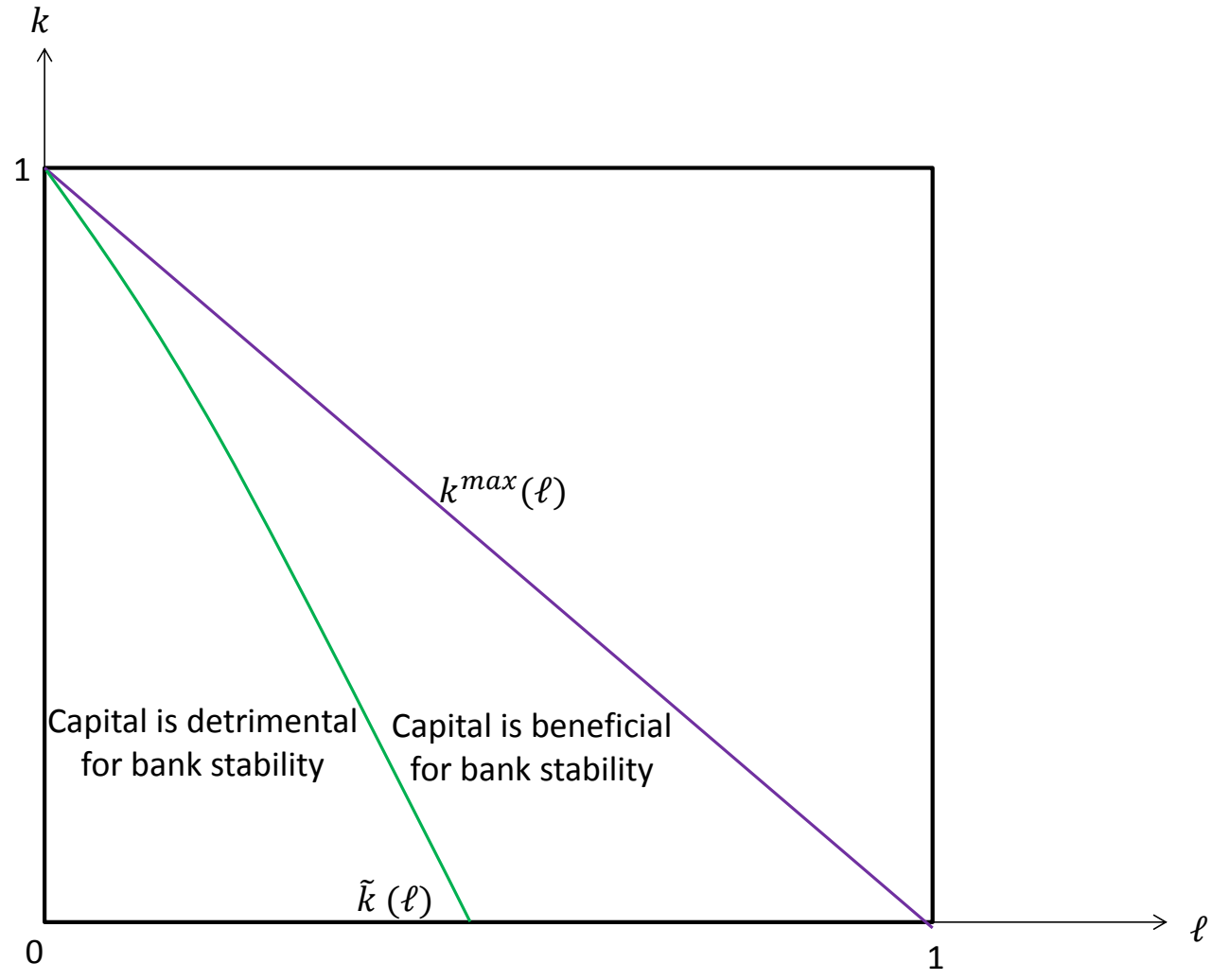
Capital, liquidity and bank fragility

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



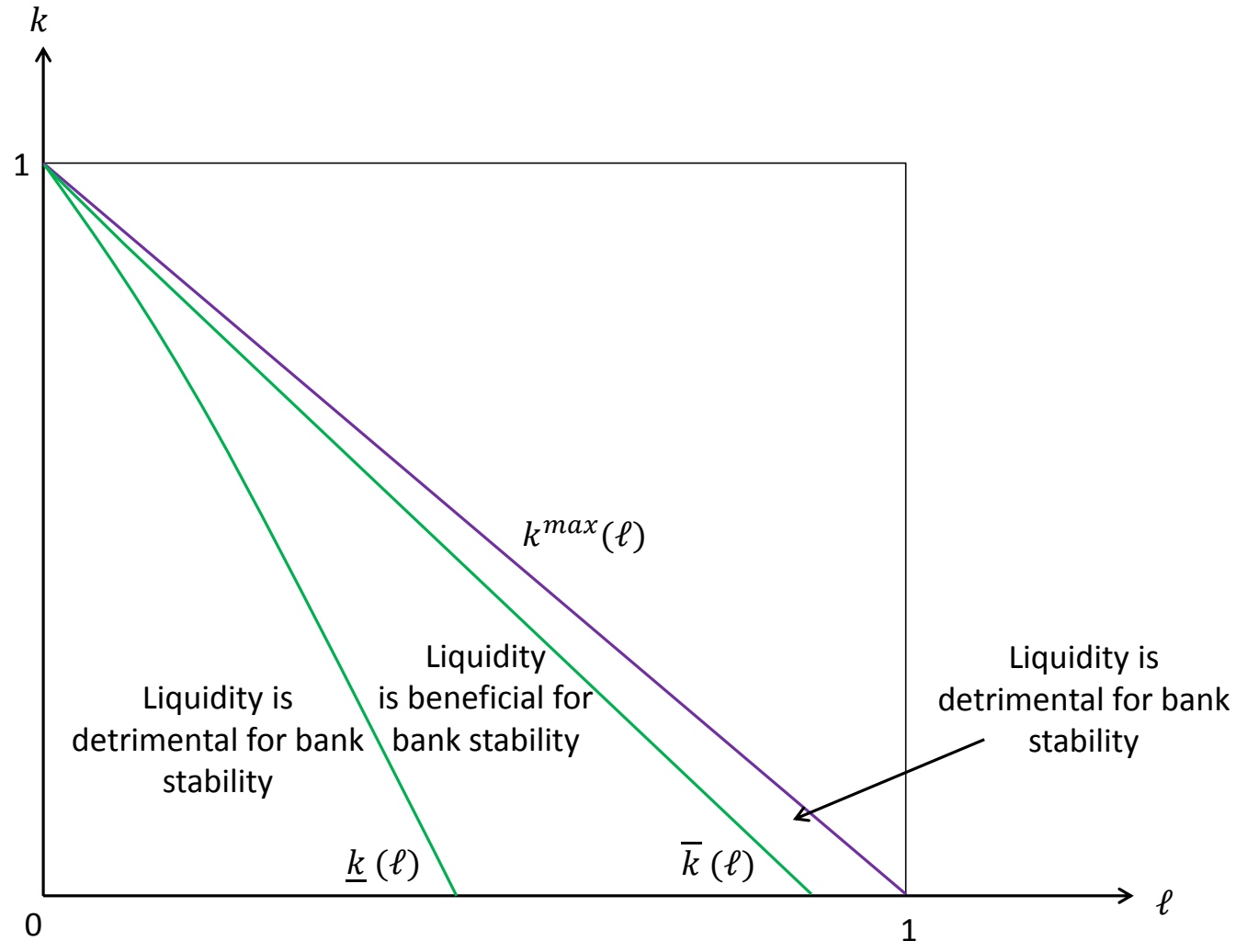
Effect of capital on crisis probability

- Banks never choose to be where capital increases crisis probability



Effect of liquidity on crisis probabilities

- Banks never choose to be where liquidity increases crisis probability



Regulatory intervention

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

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

subject to

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

- Then, it sets requirements so that $\left(1-k^R\right)=\ell^R$ holds
  - The exact point on $\left(1-k^R\right)=\ell^R$ frontier depends on how costly k and ℓ are for banks
- Capital and liquidity are **substitutes** in restoring efficiency if adequately designed

Banks in the system

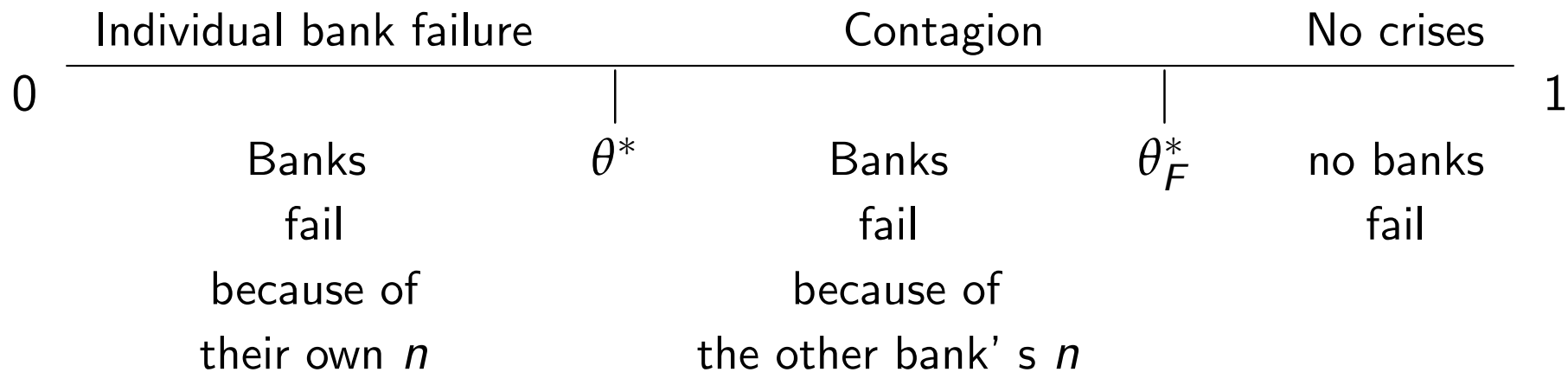
- Two banks ($i = A, B$) with the same θ (aggregate shock)
- They sell assets to outside investors with finite wealth and ability w in a common asset market
- Now, bank i liquidation value is $\ell^i * \chi$, where χ depends on investors' wealth w and total amount of illiquid assets sold Q

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

  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)



RF

Banks' choice

- Banks problem is as before, but
  - Crisis threshold is θ_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:

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

  - Fire-sales losses:

$$\int_{0}^{\theta_F^*} \ell\left[1-\chi\left(Q^{tot},w\right)\right] d\theta$$

Regulatory intervention

- Regulator sets capital and liquidity requirements $\left\{k^R, \ell^R\right\}$ to minimize

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

  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 $\left(1-k\right) = \ell\chi\left(.\right)$) still leaves inefficient liquidation and fire sales losses (i.e., $\theta_{FS}^* \rightarrow \underline{\theta} > \theta^E$ and $\chi = \chi\left(Q^{tot}, w\right) < 1$)
- Banks must be forced to hold a sufficient amount of liquidity so that $\chi = 1$ and capital should be set to satisfy $\left(1-k\right) = \ell$
  - **But**, this may not feasible if α and ρ 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

$$\frac{\text{Stock of } \textit{HQLA}}{\text{Total net cash outflows over 30 days}} \geq 100\%$$

  - 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

$$\frac{\text{Total } \textbf{available} \text{ stable funding (ASF)}}{\text{Total } \textbf{required} \text{ stable funding (RSF)}} \geq 100\%$$

  - 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

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(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

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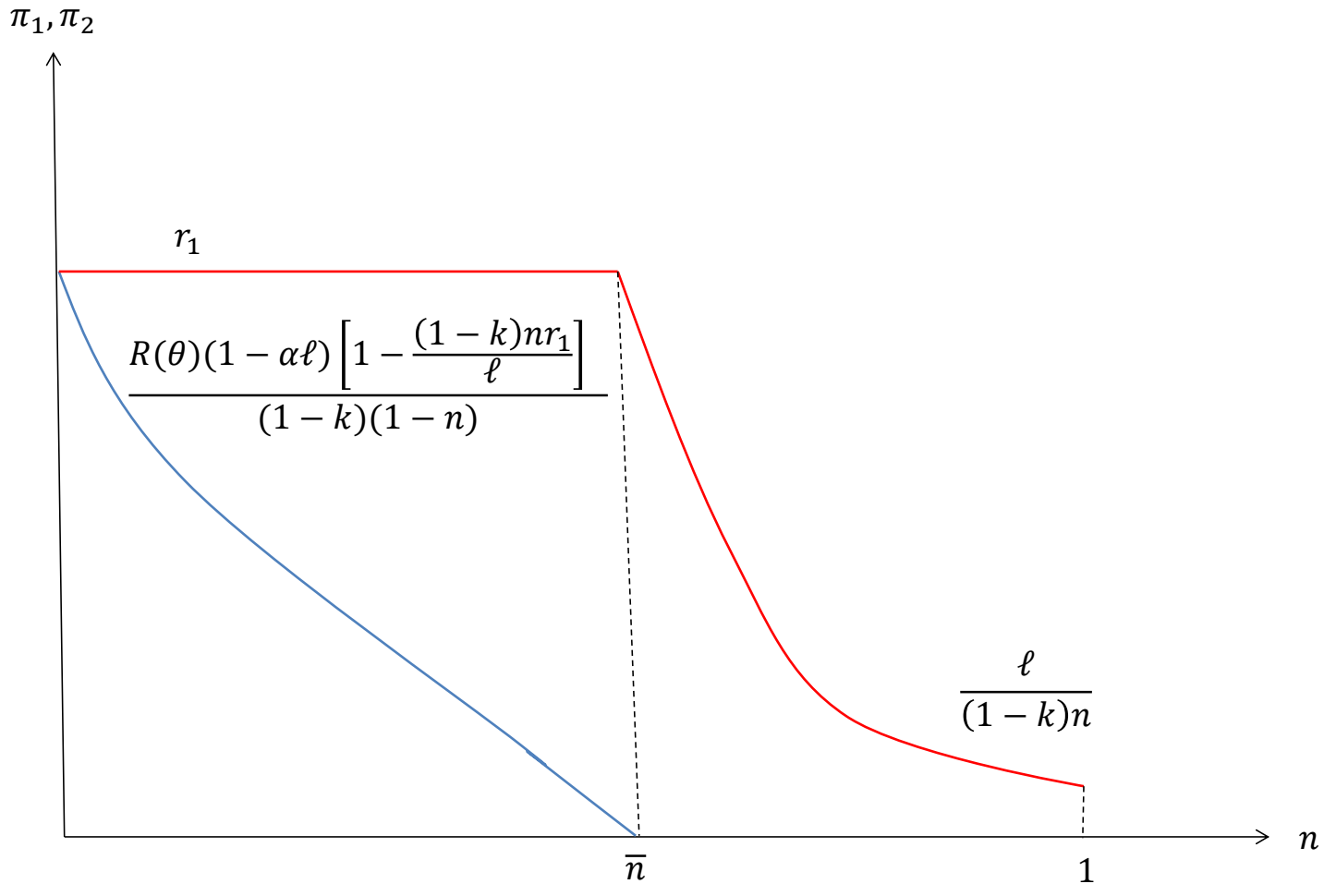
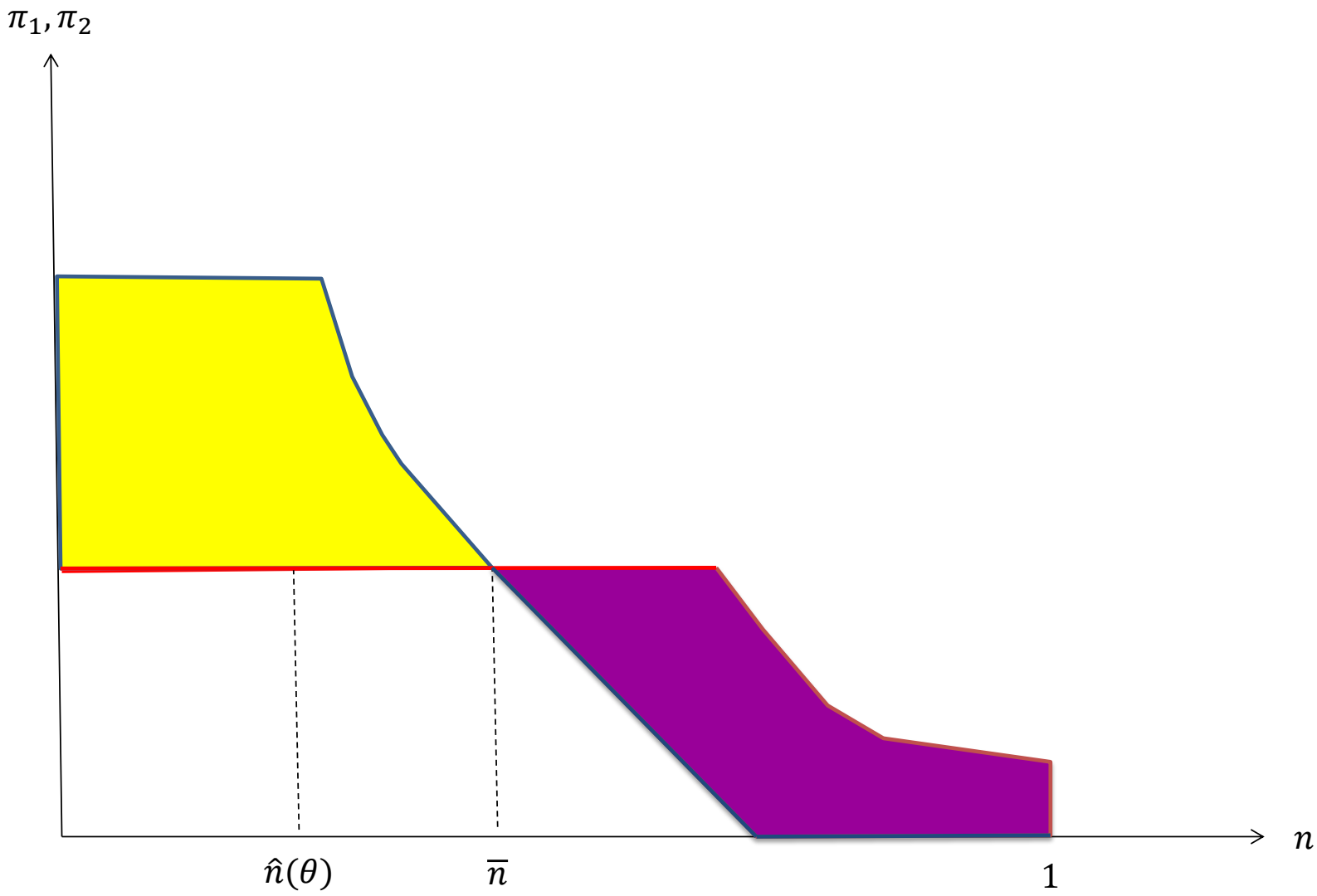
Solvency crises

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



Liquidity crises

- For any $\theta > \underline{\theta}$, 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 ℓ

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

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Reaction functions