Joint liquidity and capital regulation with a lender of last resort

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Liquidity in the regulatory focus

- Before the 2007-2008 crisis, regulatory focus was mainly on **insolvency risk**
  - Basel II: capital requirements

- But the early **liquidity phase** of the financial crisis disclosed severe weaknesses on liquidity holdings (e.g. Northern Rock)

- Regulators turned their attention to **illiquidity risk**
  - Basel III: Liquidity Coverage Ratio and Net Stable Funding Ratio (liquidity requirements)

- But it is unclear which effects **liquidity requirements** will have and whether and how they should **relate to capital requirements**
  - Basel III liquidity and capital regulation have followed a "**silo approach**" (independent committees with different objectives)

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  - **Liquidity requirements** typically set to reduce illiquidity risk: Allen and Gale (JPE'00), (Farhi, Golosov and Tsyvinski (REStud'09), Perotti and Suarez (IJCB'11); Freixas, Martin and Skeie (RFS'11); Calomiris, Heider and Hoerova (WP'15))

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  - **We characterize the optimal joint regulation of liquidity and capital** taking feedback loops into consideration

Related literature: liquidity and capital regulation

- **Vives (RFS'14)**: Insolvency risk (and degree of transparency) affects illiquidity risk through a strategic complementarity to run on the bank's debt
  - Capital requirements and disclosure rules should be jointly determined with liquidity requirements (Focus on **roll-over debt**)

- **Walther (JMCB'16)**: Optimal regulation to reduce a **fire-sales** pecuniary externality that banks do not internalize

- **De Nicolò, Gamba and Luchetta (RFS'14)**: **Numerical illustration** of effects of capital and liquidity requirements (the latter always welfare reducing!)

- **Our paper**: Liquidity shocks exogenous, no fire-sales externalities, close-form solutions, focus on **bank's risk-shifting**

Model building blocks

- **Insolvency risk**: Standard risk-return trade off (increasing return requires increasing risk) *à la* Dell'Ariccia and Marquez (JFE'06) and Allen, Carletti and Marquez (RFS'11)
- **Illiquidity risk**: Early deposit withdrawals *à la* Diamond and Dybvig (JPE'83) –we add aggregate uncertainty in deposit withdrawals
- **Deposit insurance**
- **Limited liability** for banks
- **Costly capital**

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  - **Capital** requirements reduce **insolvency risk** ('skin in the game')
  - **Liquidity** requirements reduce **illiquidity risk** (higher buffer to cope with early withdrawals)

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  - Reduces insolvency risk: higher opportunity cost of liquidity (capital **offsets liquidity**)

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- Equilibrium **capital-liquidity requirements: complementary or offsetting** depending on opportunity cost of liquidity and capital
- A **Lender of Last Resort p**artially substitutes liquidity, making capital and liquidity **offsetting tools**

Model

Setup

- Four period economy: $t = \{-1, 0, 1, 2\}$
- Risk-neutral agents
- No discount factor
- Single bank

Liquidity and capital requirements (t=-1)

Figure: Timeline of the model

- At $t = -1$ the regulator establishes a liquidity l^* and a capital k^* requirement (only verifiable variables)

Bank's choices (t=0)

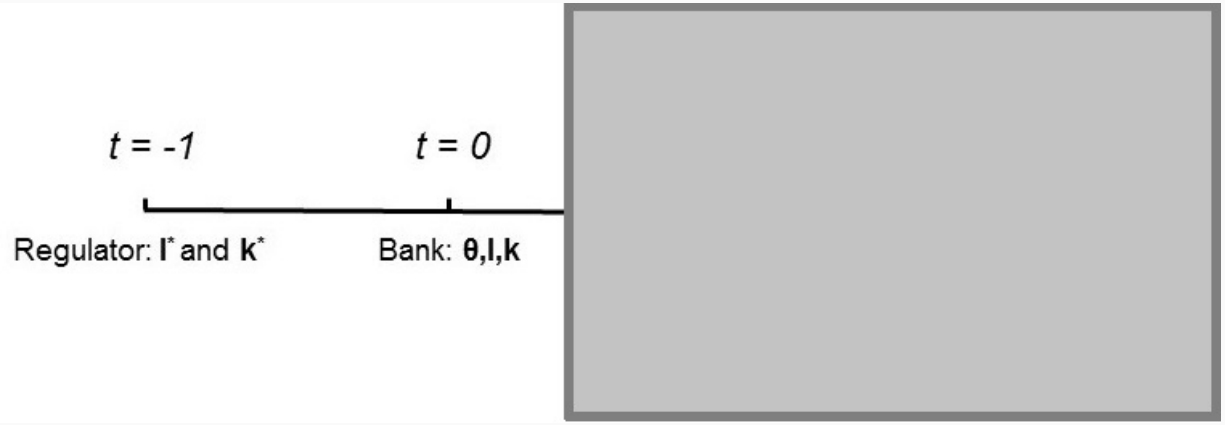

Figure: Timeline of the model

At $t = 0$ the bank chooses:

- Capital structure: capital, long term deposits and common deposits
- Assets: liquid assets and loans
- Insolvency risk

Bank's capital structure

- Normalized size to 1
- **(Equity) capital**: **k**
  - Capital requirements: $k \geq k^*$
- **Insured deposits**: $\mathbf{1 - k}$
  - **Common** deposits: **d**
    - Subject to early withdrawals
    - Interest rate: 1
  - **Long-term** deposits: $\mathbf{b \equiv 1 - d - k}$
    - Not withdrawable until maturity
    - Interest rate: $1 + r \geq 1$
- Assumption costly capital: $\rho > r$

Bank's assets

- Keep $l \geq l^*$ of liquid assets (cash)
- Invest $1 - l$ in loans

Insolvency risk

- Bank chooses probability of success $\boldsymbol{\theta}$ at cost $\frac{\mathbf{c}}{\mathbf{2}} \cdot \boldsymbol{\theta}^{\mathbf{2}}$
    - Insolvency risk: $1 - \theta$

Liquidity phase (t=1)

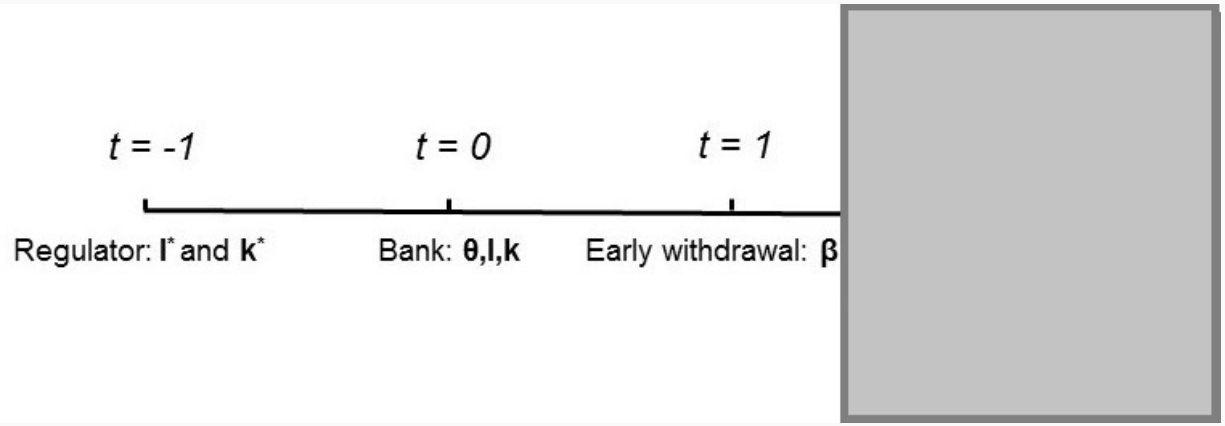

Figure: Timeline of the model

At $t = 1$, the bank faces an amount β of early withdrawals, where

- $\beta \sim F[0, d]$, F **log-concave** (e.g. uniform, beta distribution, power,...) and absolutely **continuous**, f **positive** in interior of support

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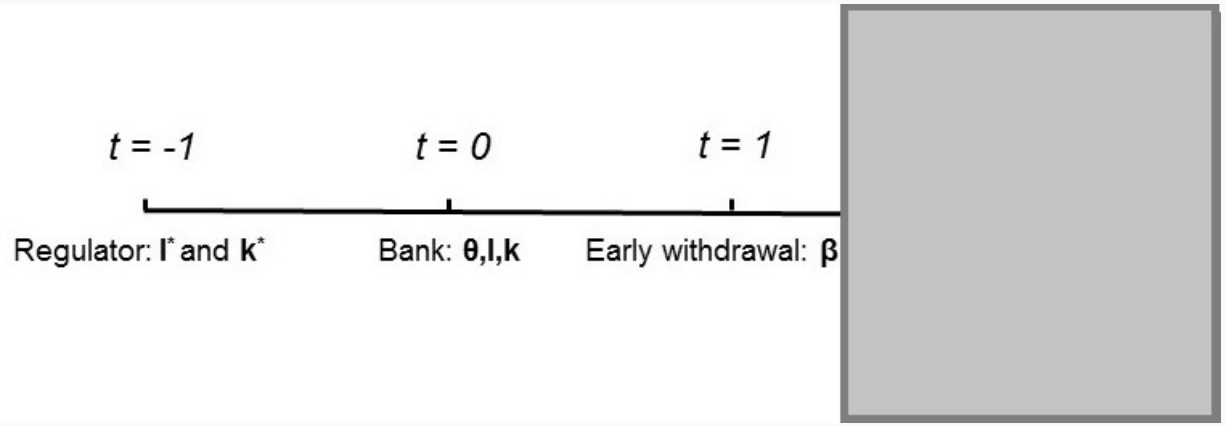

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    - Illiquidity risk: $1 - F(l)$

Loan maturity phase (t=2)

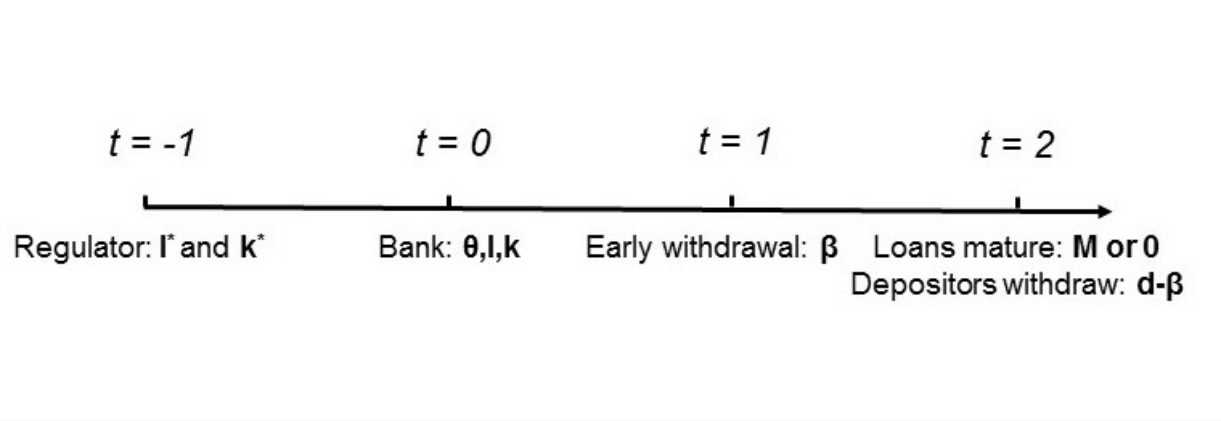

Figure: Timeline of the model

- Loan matures:
  - If successful: **M**
  - If failure: **0**

Bank's choice of insolvency risk

Outline

- Model
- **Bank's choice of insolvency risk**
  - Effect of liquidity requirements on insolvency risk
  - Effect of capital requirements on insolvency risk
- Regulation
  - Regulator's problem
  - Optimal requirements
    - Optimal capital with predetermined liquidity
    - Optimal liquidity with predetermined capital
    - Joint optimal capital and liquidity requirements
  - Capital and liquidity: complementary or offsetting?

Bank's choice of insolvency risk

- Given liquidity l and capital k, the bank chooses θ to solve:

$$\left.\begin{array}{ll} \max_{\theta \in [0,1]} & \Pi_B(\theta, l, k) \\ s.t. & \Pi_B(\theta, l, k) \geq 0 \end{array}\right\},$$

Bank's objective function

$$\Pi_B(\theta, l, k) \equiv \int_0^l \theta \cdot \Bigg[\overbrace{\underbrace{\underbrace{M \cdot (1-l)}_{\text{Loan Value}} + \underbrace{l-\beta}_{\text{Cash}}}_{\text{Assets}} - \underbrace{(1-k-\beta+b\cdot r)}_{\text{Deposit Liabilities}}}^{\text{Upside payoff: } \pi(l,k)} \Bigg] \cdot f(\beta)\, d\beta$$

$$- \underbrace{\frac{c}{2} \cdot \theta^2}_{\text{Cost reducing insolvency risk}} - \underbrace{(1+\rho)\cdot k}_{\text{Cost of Equity}}$$

Bank's objective function rearranged

$$\Pi_B(\theta, l, k) = \underbrace{\theta \cdot F(l)}_{\textit{probability success}} \cdot \underbrace{\pi(l, k)}_{\textit{Upside payoff}} - \frac{c}{2} \cdot \theta^2 - (1 + \rho) \cdot k$$

Bank's upside payoff: effect of requirements

- Bank's upside payoff **decreasing in liquidity** (opportunity cost of liquidity):

$$\pi(l,k) = \underbrace{[M \cdot (1-\mathbf{l}) + \mathbf{l}]}_{Assets} - (1 - k + b \cdot r)$$

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- Bank's upside payoff **increasing in capital** (reduction of deposit liabilities–skin in the game):

$$\pi(l,k) = [M \cdot (1 - l) + l] - \underbrace{(1 - \mathbf{k} + b \cdot r)}_{Liabilities}$$

Bank's choice of insolvency risk

- Bank's problem, given (l, k):

$$\theta_B(l, k) \equiv \arg\max_{\theta} \Pi_B(\theta, l, k)$$

- FOC:

$$\theta_B(l, k) = \frac{1}{c} \cdot \underbrace{F(l) \cdot \pi(l, k)}_{\text{Expected upside payoff}}$$

Effect of regulation on insolvency risk

The effect of binding liquidity requirements on insolvency risk

Proposition (Effect of liquidity requirements on insolvency risk)

- Liquidity requirements increase insolvency risk

Bank's profit-maximizing liquidity

- Bank's profit-maximizing liquidity level is given:

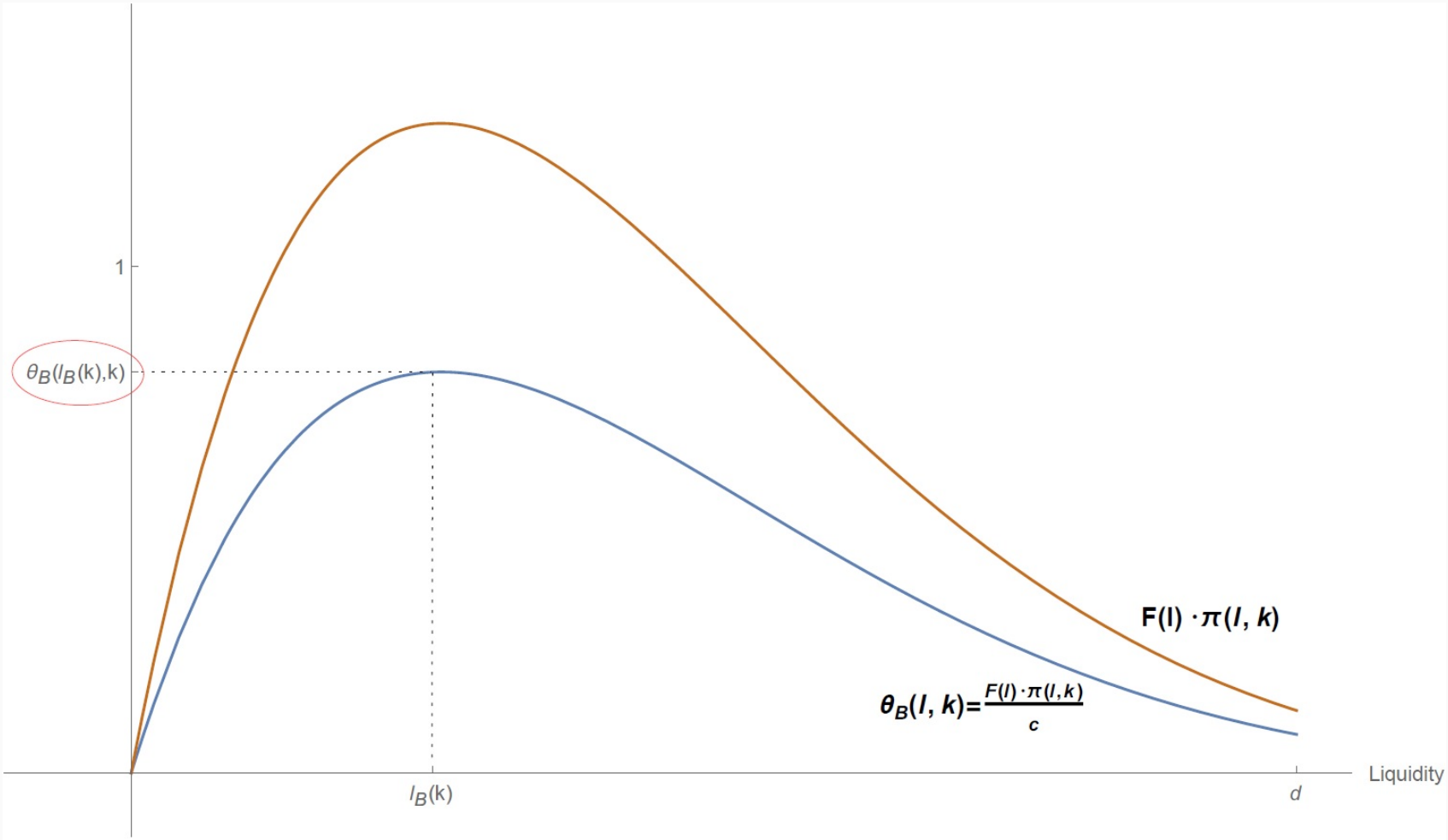
$$l_B(k) \equiv \arg\max_l \Pi_B(\theta, l, k)$$

  - Trades-off **probability of surviving** and **upside payoff:**

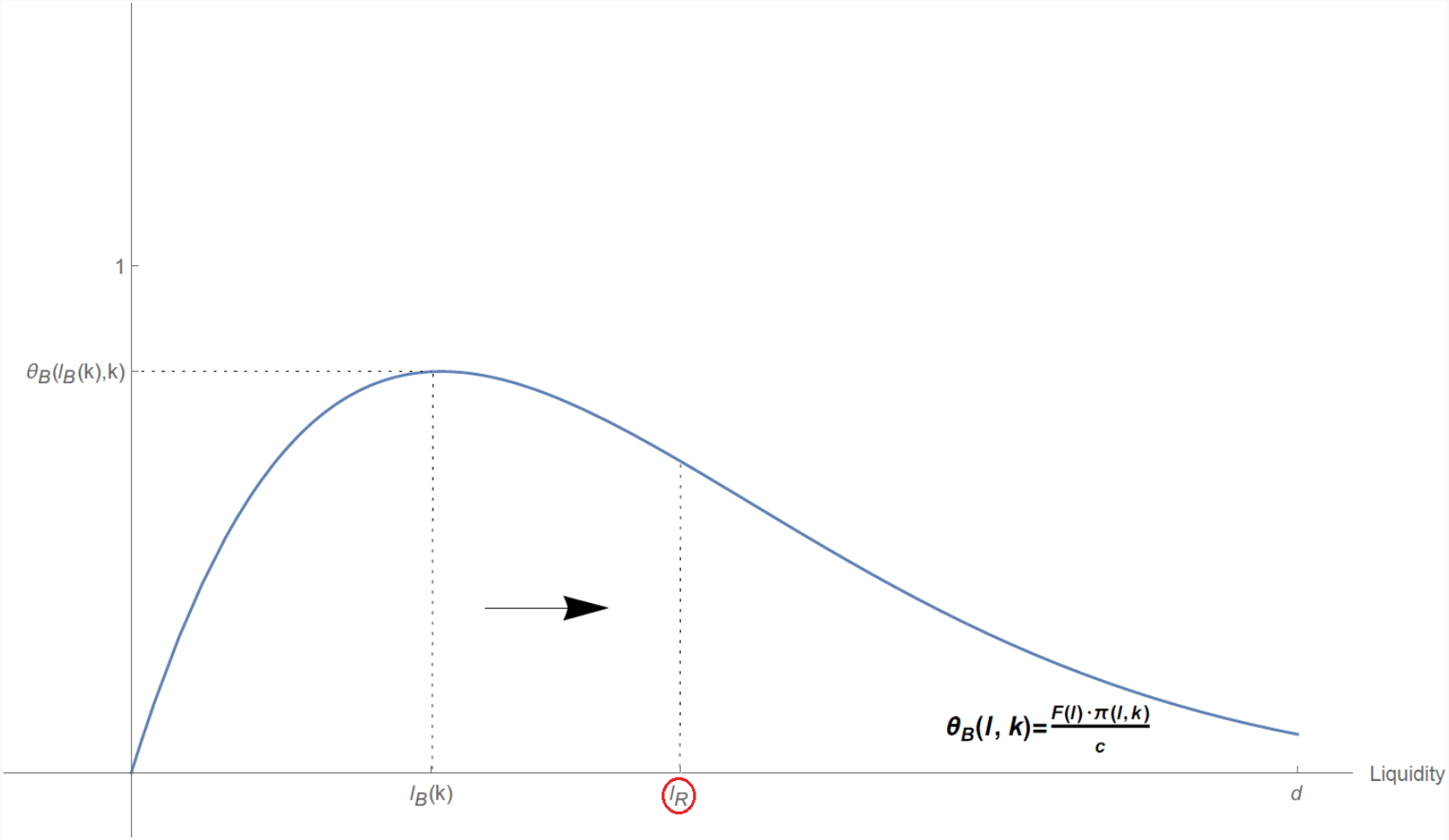
$$l_B(k) = \arg\max_l \underbrace{F(l) \cdot \pi(l, k)}_{hump-shaped\ in\ liquidity}$$

Bank's profit-maximizing liquidity

Bank's profit-maximizing liquidity and insolvency risk



Binding liquidity requirements



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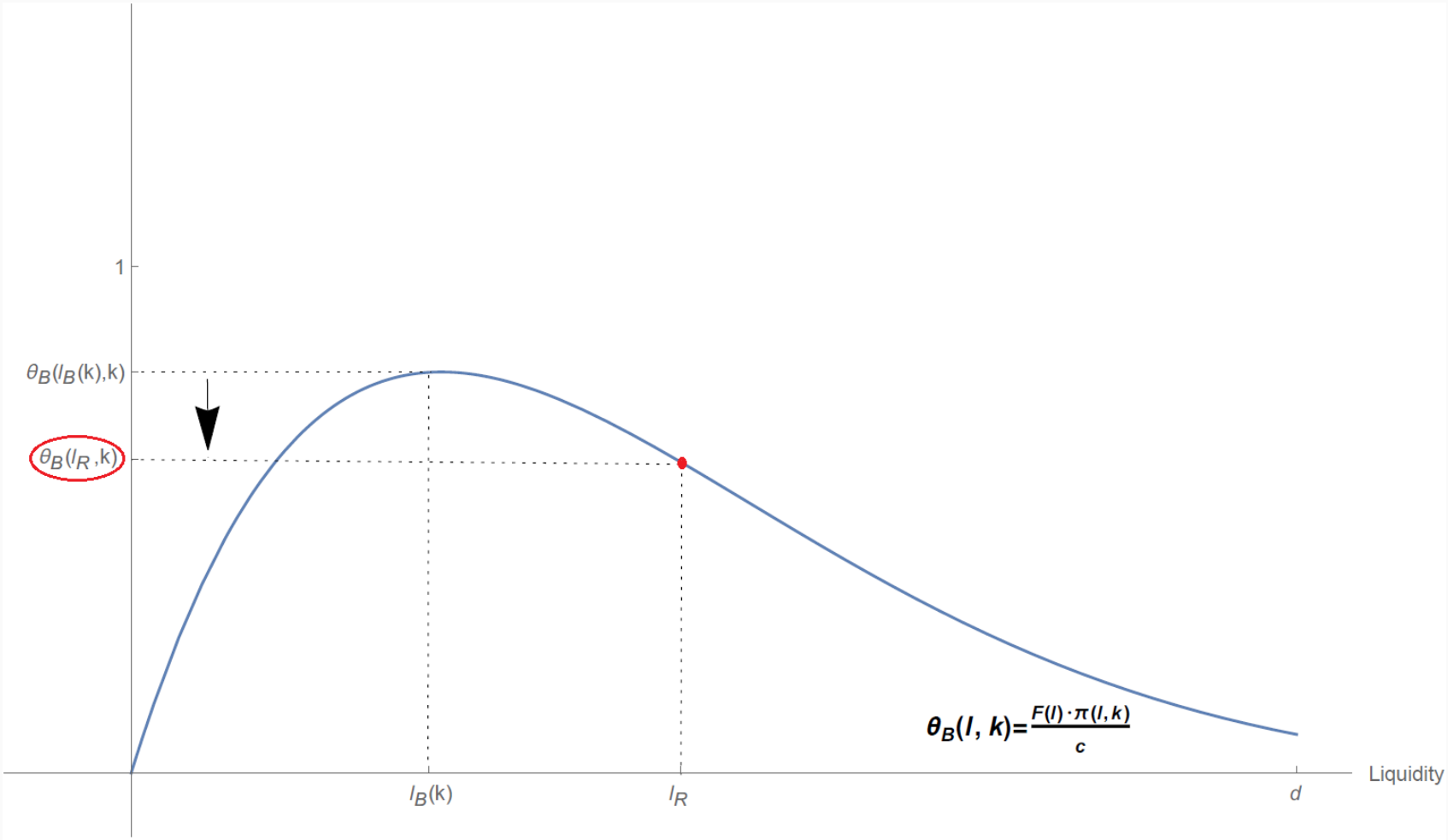

The effect of capital requirements on insolvency risk

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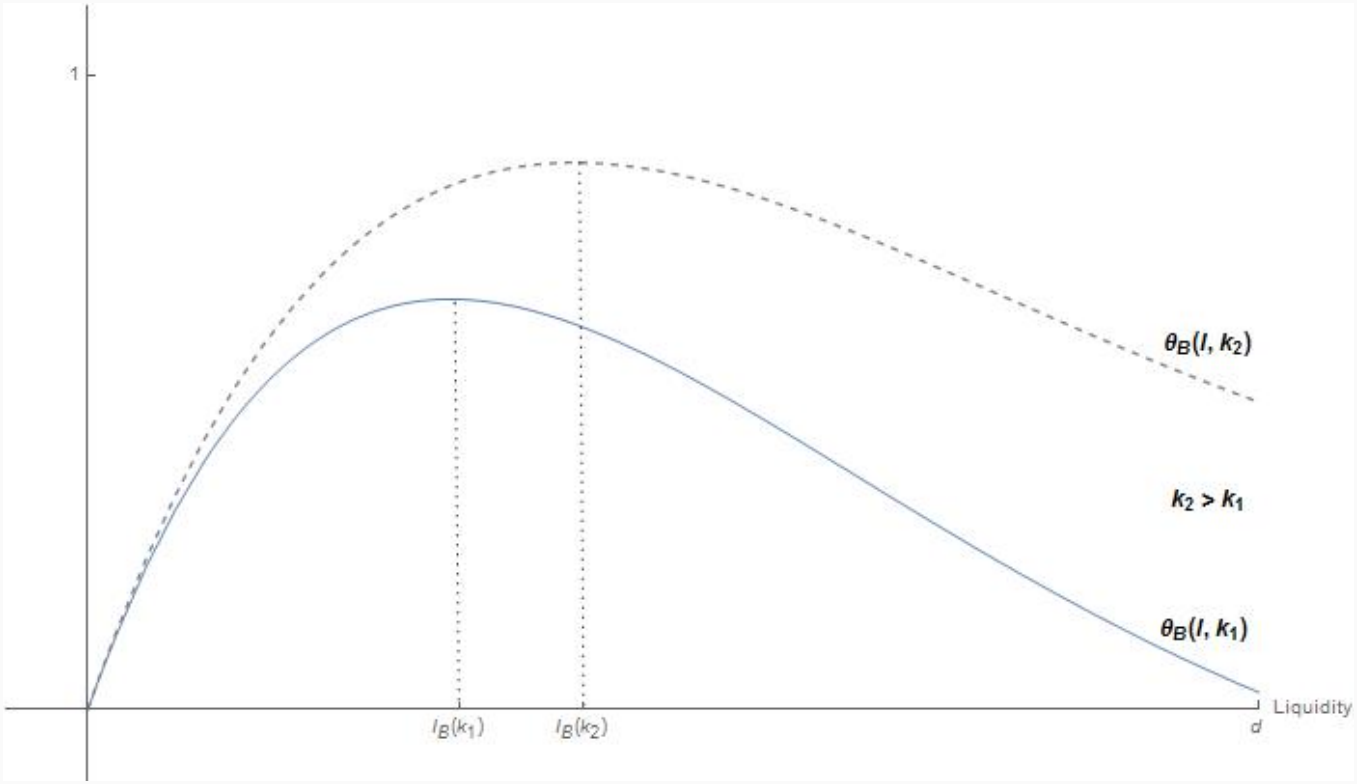
The effect of capital requirements on insolvency risk

Proposition (Effect of capital requirements on insolvency risk)

- Capital requirements reduce insolvency risk
- Capital mitigates the negative effect of liquidity requirements on insolvency risk

The effect of capital on insolvency risk: illustration

Capital reduces insolvency risk for each liquidity level and reduces negative effect of liquidity on insolvency risk



Regulation

Regulator's problem

$$\left.\begin{array}{ll} \max_{l\in[0,d],k\in[0,1-d]} & \Pi_R\left(l,k\right) \\ s.t. & \Pi_B\left(\theta_B\left(l,k\right),l,k\right)\geq 0 \end{array}\right\}$$

Regulator's objective function

$$\Pi_R(l,k) \equiv \Pi_B(\theta_B, l, k) - \underbrace{\left(1 - \theta_B(l,k) \cdot F(l)\right)}_{\text{Pr. } \textit{Failure}} \cdot \underbrace{D(l,k)}_{\text{Bank's net liabilities}},$$

where

$$D(l,k) \equiv \underbrace{\left(1 - \mathbf{k} + b \cdot r\right)}_{\textit{Bank's Gross Liabilities}} - \mathbf{l}$$

- $D(l,k)$ decreasing in **liquidity** l (reduces liabilities)
- $D(l,k)$ decreasing in **capital** k (diminishes the amount of deposits)

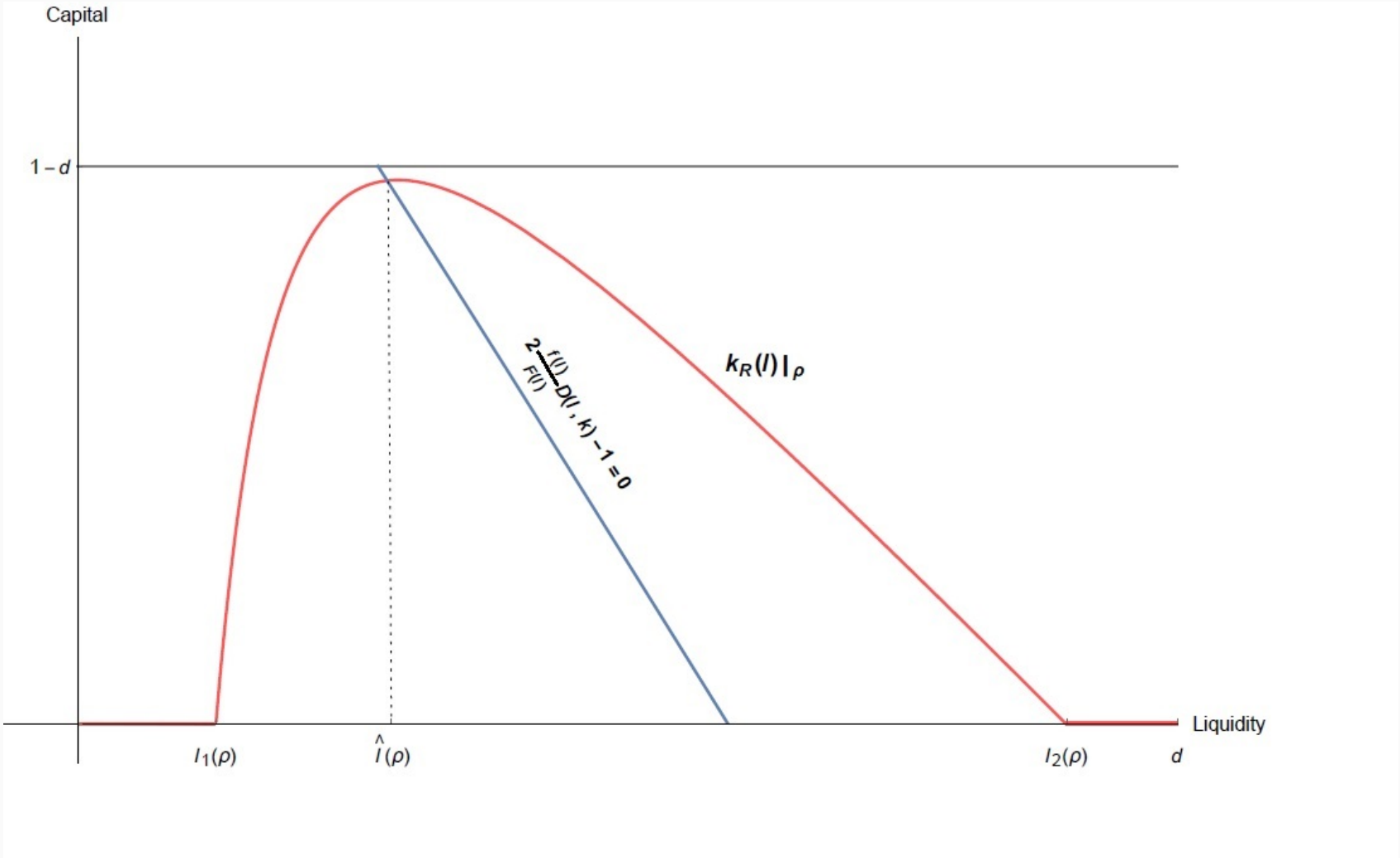
Optimal capital and liquidity requirements

1. Find optimal **capital response** $k_R(l)$ for any given level of liquidity

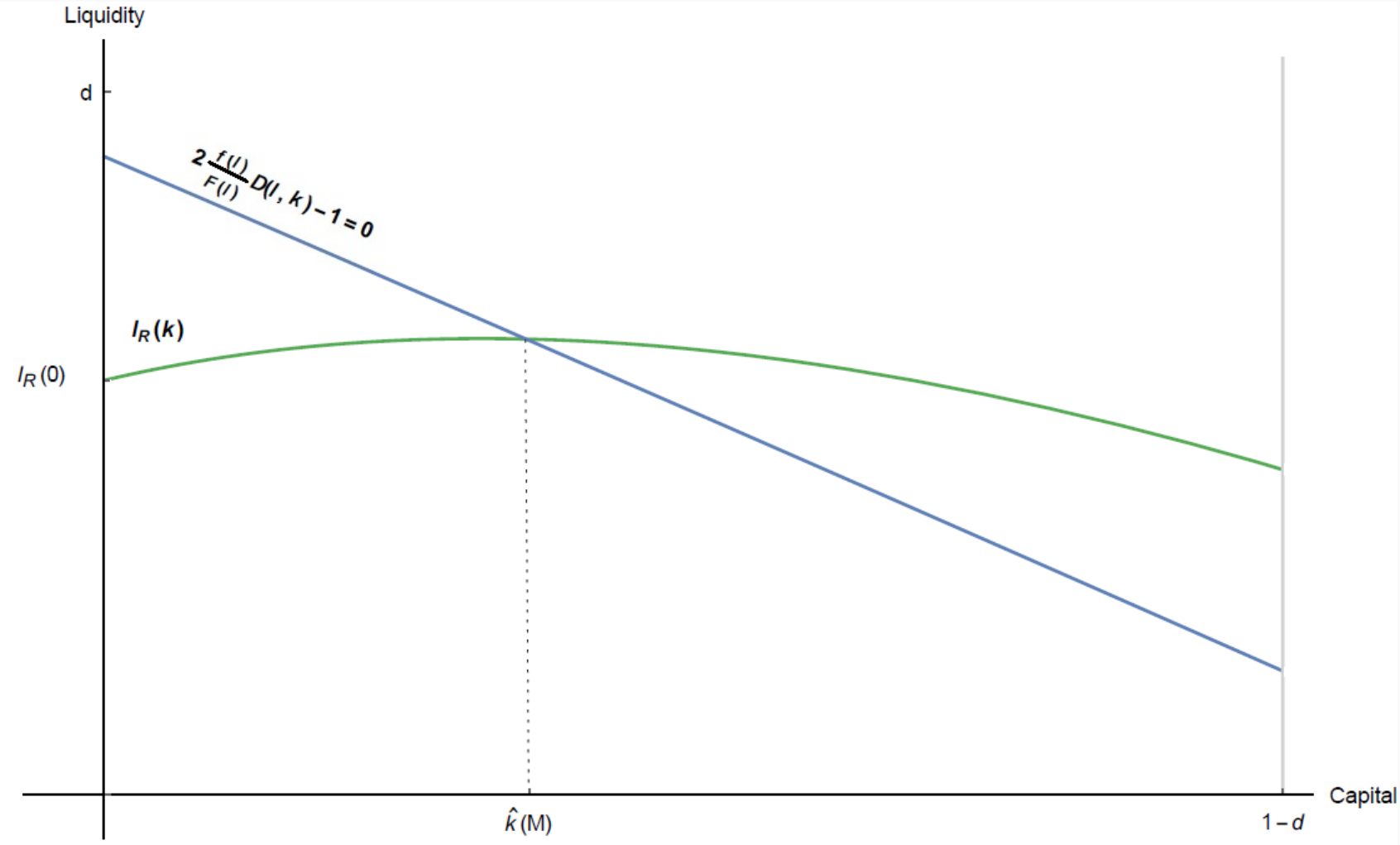
2. Find optimal **liquidity response** $l_R(k)$ for any given level of capital

3. Optimal **liquidity and capital requirements**: (l^*, k^*) such that $l^* = l_R(k^*)$ and $k^* = k_R(l^*)$

Capital response hat-shaped



Liquidity response hump-shaped



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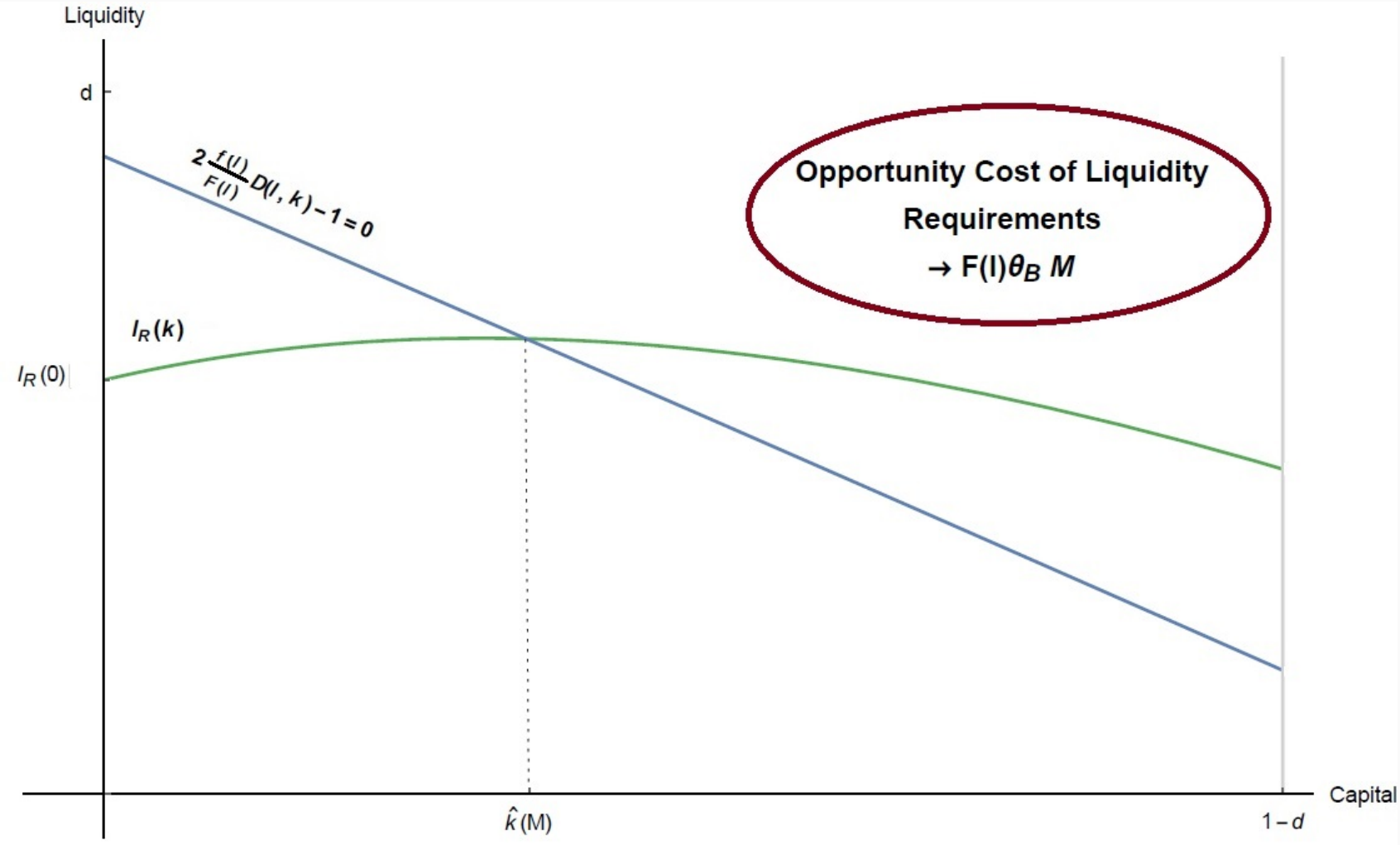
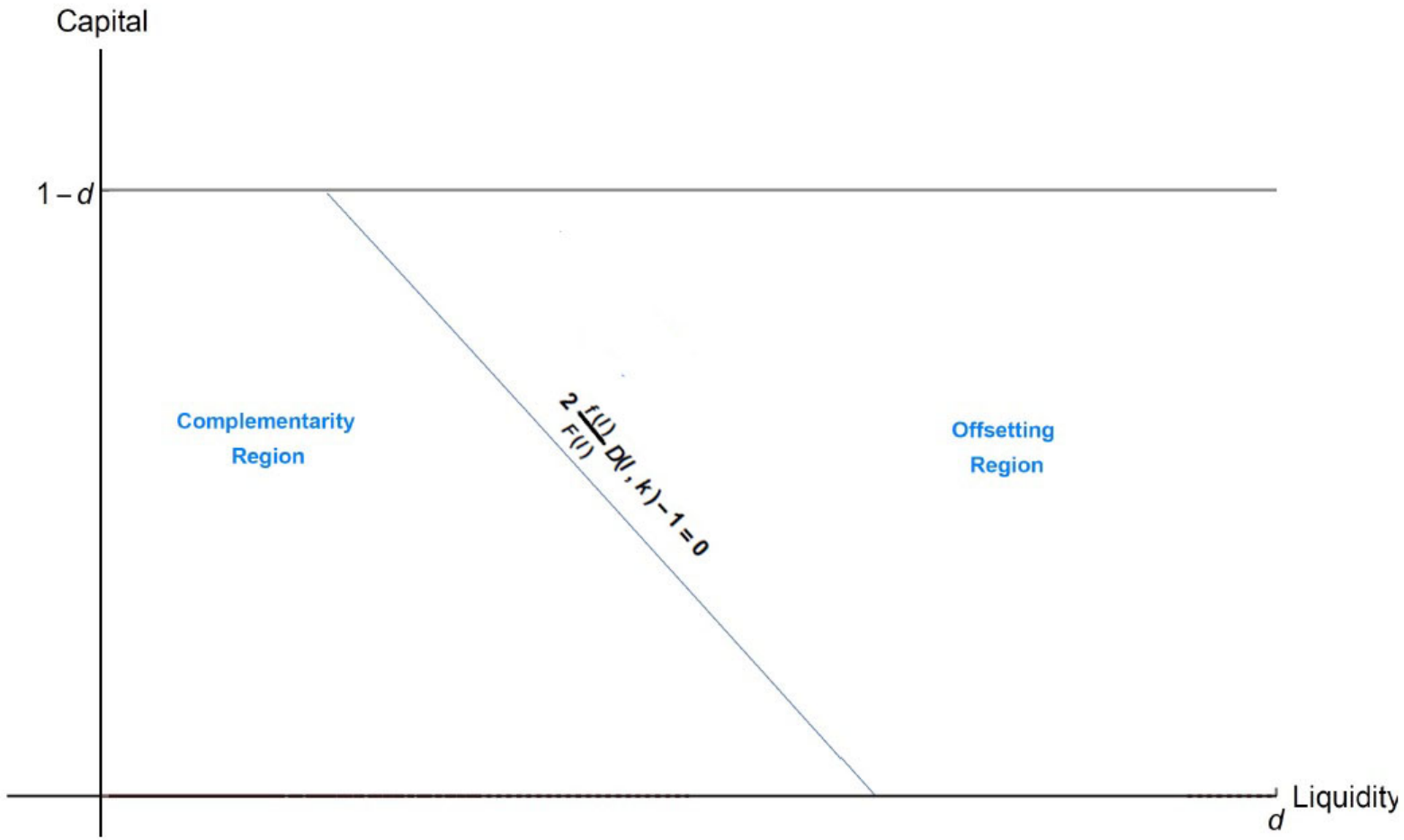


Capital and liquidity: complementary or offsetting?

Complementary and offsetting regions



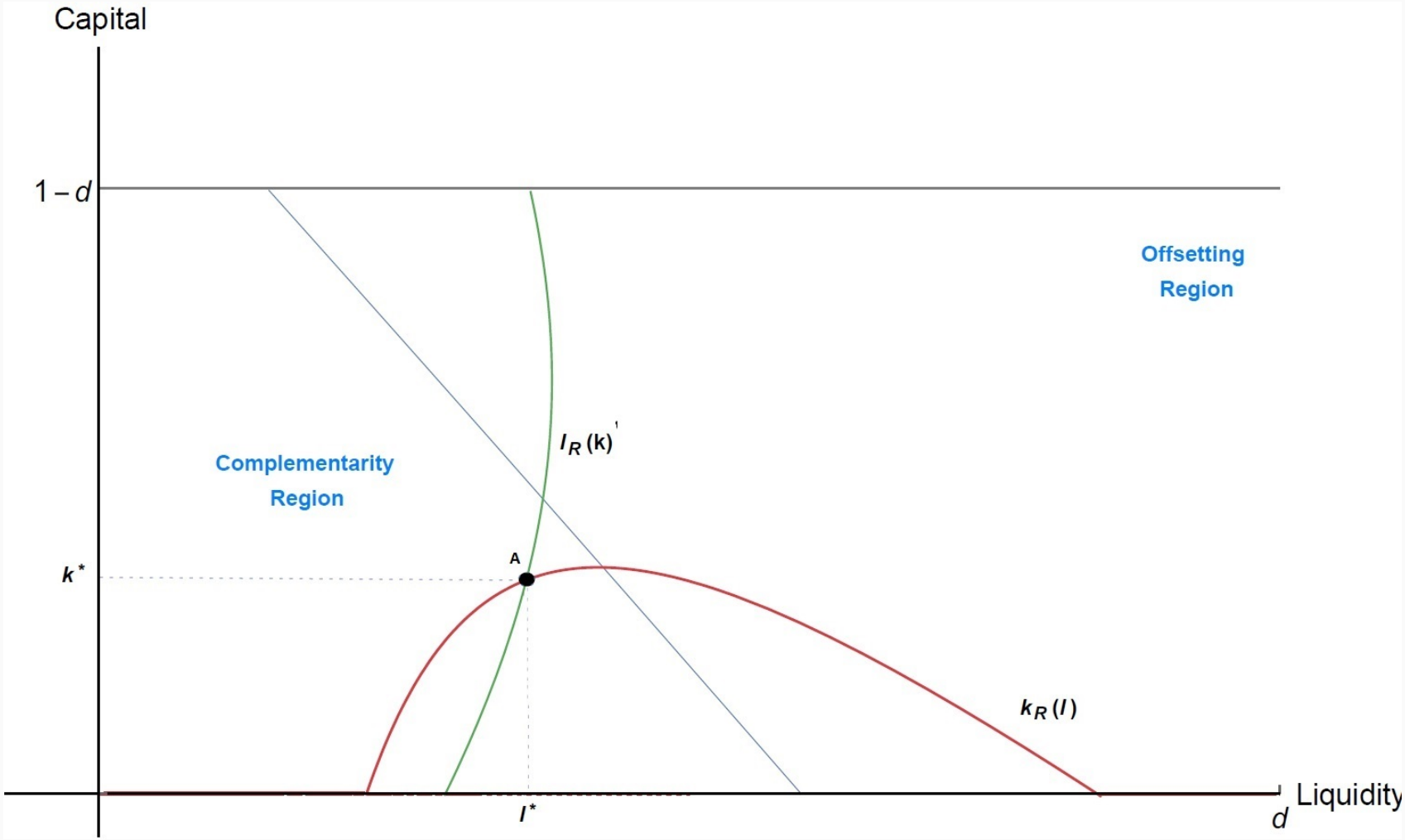
Complementary or offsetting policy tools

Proposition (Complementary or offsetting)

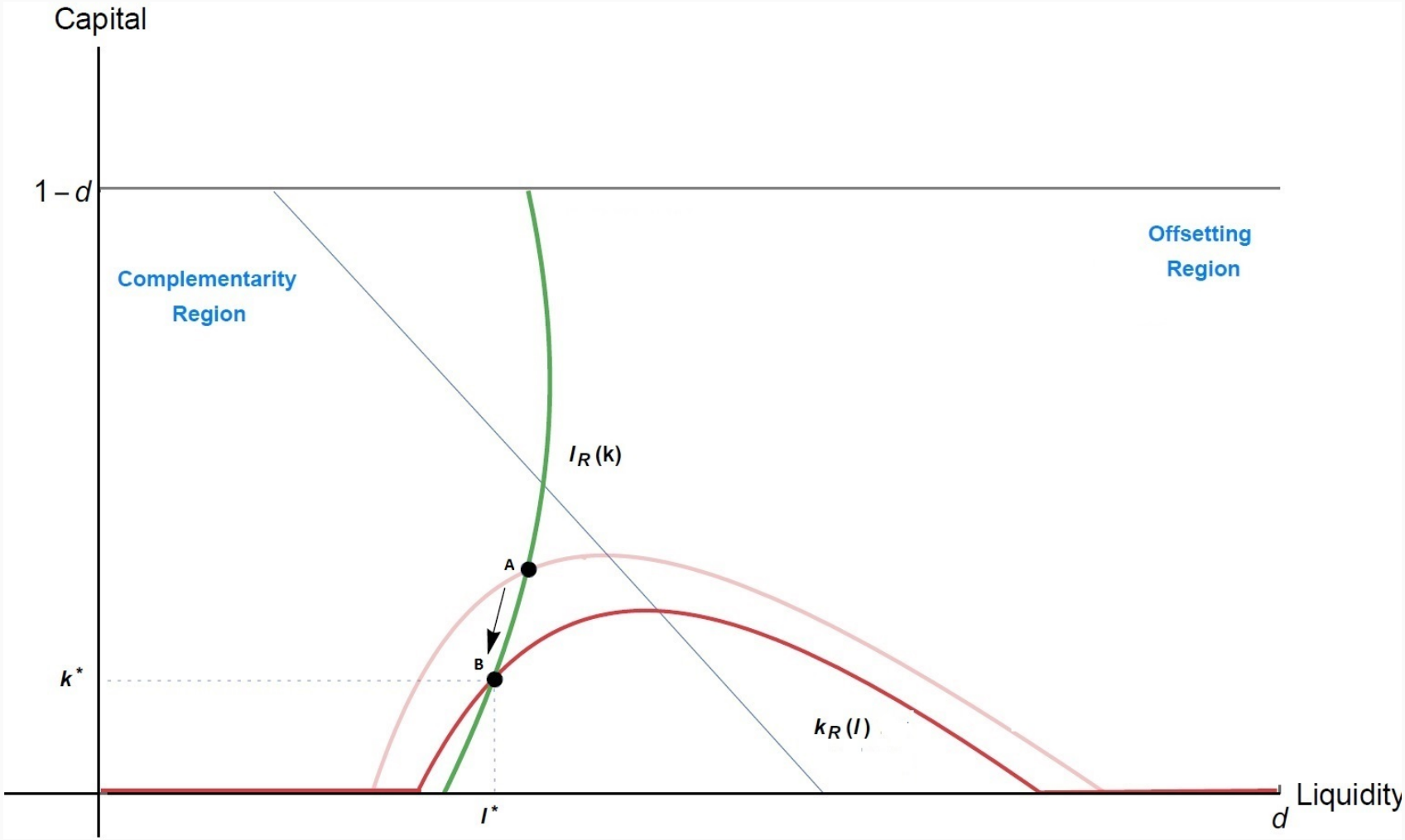
There exists a threshold $\bar{M}$, and, for each $M < \bar{M}$, there does also exist a threshold $\hat{\rho}(M)$ such that:

- Liquidity and capital are **offsetting** tools in equilibrium if $M < \bar{M}$ and $\rho < \hat{\rho}(M)$
- Liquidity and capital are **complementary** tools in equilibrium otherwise (i.e., if either $M > \bar{M}$ or if both $M < \bar{M}$ and $\rho > \hat{\rho}(M)$)

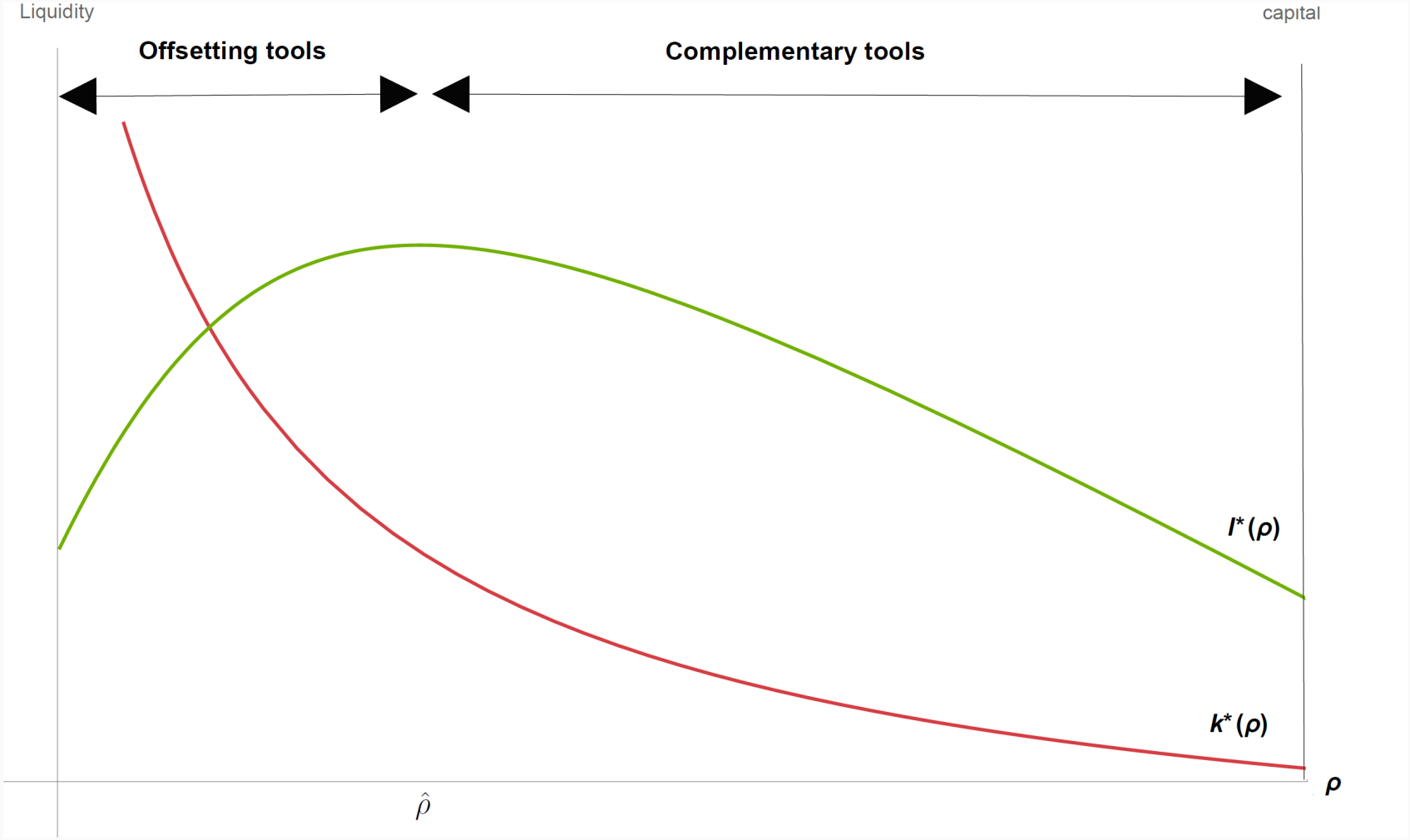
Equilibrium with $\rho_1 > \hat{\rho}(M)$ and $M_1 < \overline{M}$: Complementary



Complementarity region: the higher ρ, the lower l^*



The effect of level of ρ on the optimal regulatory policy



Regulation with a Lender of Last Resort

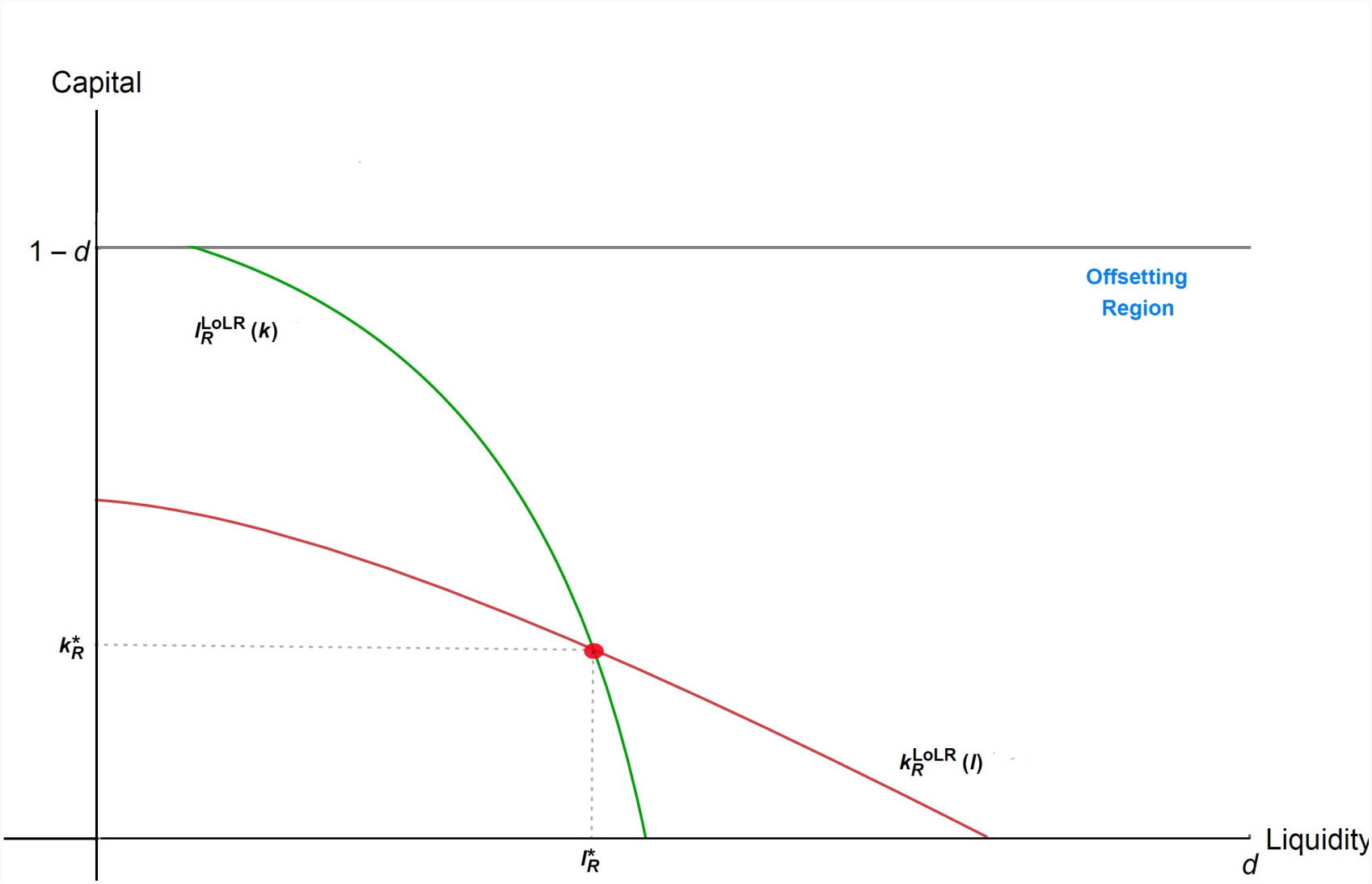
Lender of Last Resort: Assumptions and Implications

- LoLR observes whether bank is solvent (As in Rochet and Vives, 2004)
- LoLR lends to a solvent bank
- LoLR lends at rate γ, which is the opportunity cost of its founds.
- LoLR only lends if bank can return funds
  - $\beta < \overline{\beta}(I,k) = I + \frac{M(1-I)-D(I,k)}{\gamma-1}$
    - ***Remark:*** $\overline{\beta}(I,k)$ increasing in k (k reduces illiquidity risk)

Lender of Last Resort: Results

- **Higher capital** requirements: $k^{LoLR} > k^*$
- **More solvent** (for given liquidity and capital): $\theta_B^{LoLR}(I, k) > \theta_B(I, k)$
- **Lower liquidity** requirements: $I^{LoLR} < I^*$
- For $\gamma \leq \overline{\gamma}$, where $g(\overline{\beta}(0,0))\left(1 - \frac{M-1}{\gamma-1}\right) = \frac{1}{2D(0,0)}$, **capital and liquidity are offsetting tools**

Liquidity and capital offsetting tools with a LoLR



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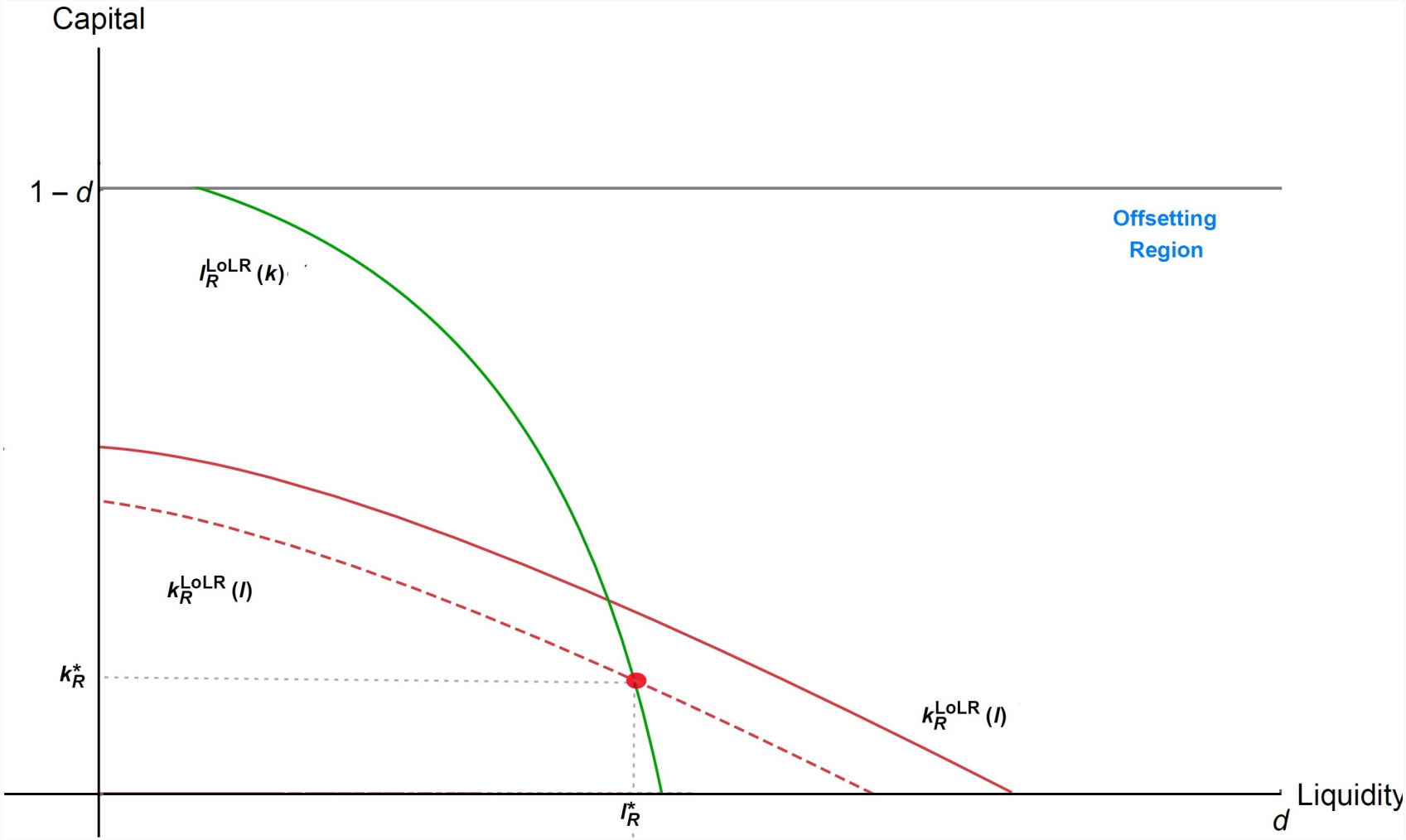
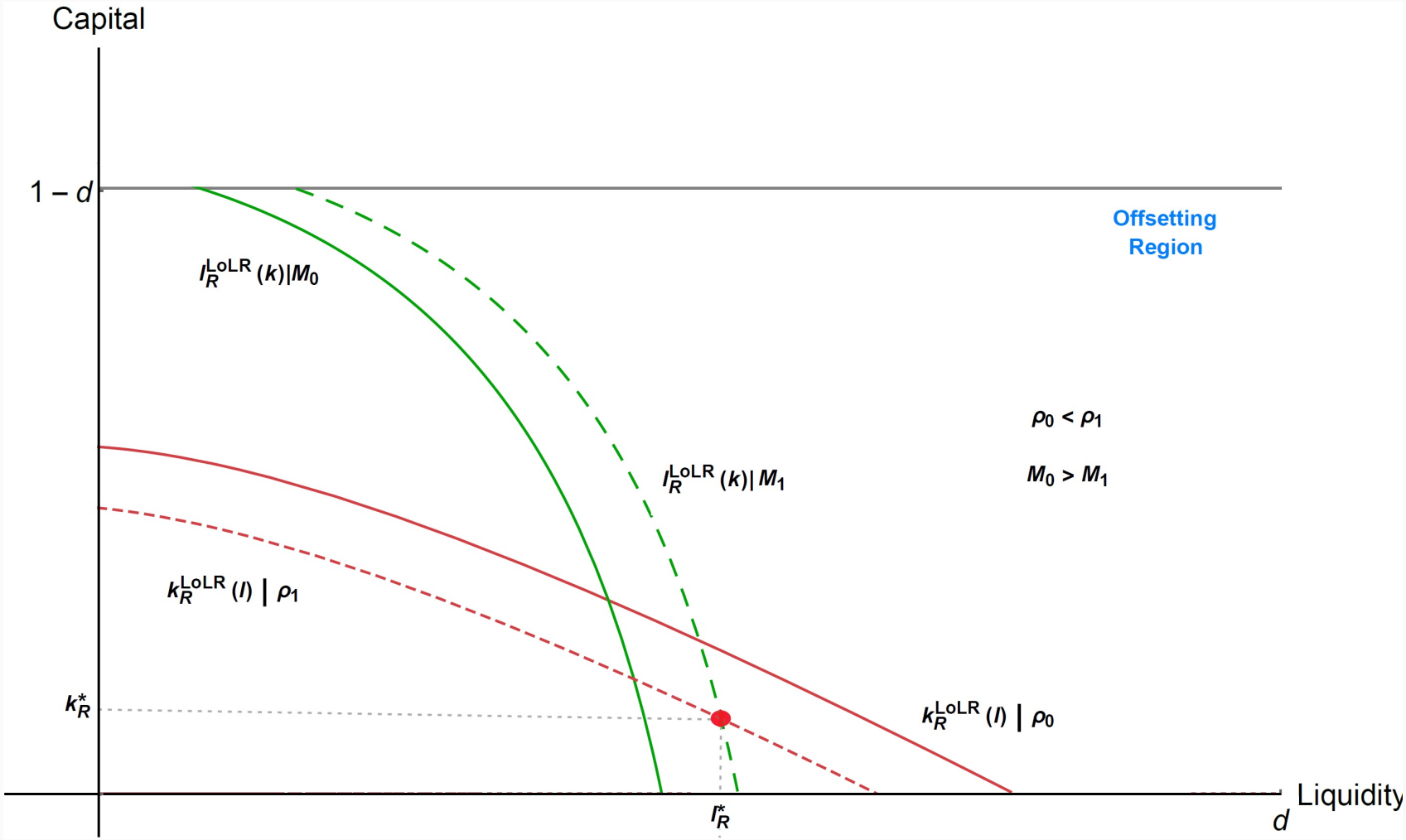


Liquidity and capital offsetting tools with a LoLR



Concluding Remarks

Conclusion

- How should capital and liquidity be **jointly** regulated?
  - We address this question with a focus on bank's **risk-taking** channel
- We identify a **feed-back loop between capital and liquidity**: the effectiveness of either instrument depends on the level of the other instrument
  - Liquidity and capital **complement** each other when both requirements are "**low**"
  - Liquidity and capital **offset** each other when both requirements are "**high**" and in the presence of a **Lender of Last Resort**
- Capital and liquidity should be regulated jointly taking into account these feedback loops
  - **Equilibrium** regulation depends on **shadow cost** of both policy tools and **availability of liquidity from other sources** (LoLR, interbank, liquidation,...)
  - **Capital and liquidity requirements should be set jointly**