# *How does macroprudential regulation change bank credit supply?*[1]

Anil Kashyap Dimitrios Tsomocos Alexandros Vardoulakis

[1]Disclaimer: The views expressed are those of the authors and do not necessarily represent those of the Federal Reserve Board of Governors or anyone in the Federal Reserve System.

# Outline

# Motivation

- Propose a model where the banking sector has the following functions:
  1. Provides liquidity insurance
  2. Enhances sharing of aggregate risk
  3. Expands credit extension to the real economy
- Study the externalities emerging from intermediation and examine regulation to mitigate their effect
- We modify the classic Diamond-Dybvig model to address these issues

# Our modifications to DD

1. Assume that runs depend on fundamentals and are not just due to sunspots
2. Assume loans are made to fund a risky technology
3. Assume the banks and the borrowers are subject to limited liability

Consequences of these modifications:

- Runs create a risk that can result in under-investment
- Limited liability creates an incentive for excessive risk-taking

**Basic Diamond-Dybvig**

t=1
Riskless loan
funded by deposits

t=2
Idiosyncratic
preference shocks

t=3
Certain investment
outcome

No bank run
Totally random

Investment
payoff

Bank run
Totally random

Early investment liquidation

**Our Framework**

t=1
**Risky investment funded by deposits & equity**

t=2
Idiosyncratic
preference shocks

t=3
**Uncertain investment outcome**

No bank run
**Function of fundamentals**

Investment
payoff
**Loan and deposits repayment**

Bank run
**Function of fundamentals**

Early investment liquidation

# The Agents

- A continuum of poor entrepreneurs (P) who owns the rights to a project but must borrow to implement it
- A continuum of rich savers (R) who can invest in a riskless asset, or make a bank deposit, or buy bank equity
    - Idiosyncratic liquidity shocks in intermediate period to consume early or late
    - Proportion of early consumers fixed, but shocks are private information and cannot be hedged
- A continuum of bankers (B) who has some trapped equity that can only by used for lending
    - B can also raise funds from R, to invest in P and the riskless asset

# Contract restrictions

- No short sales (against either P or B)
- **Limited liability for B and P**
- B acts like a "Lucas household": one side of her brain manages the assets of the bank, the other side **independently** decides what to do with her wealth
- Market incompleteness means we cannot decentralize a planner's problem
- We calibrate so that P defaults in the medium and low states, and B defaults on deposits in the low state

# P's Optimization problem

$$\max \bar{U}^P = U^P\left(c_1^P\right) + q \cdot \sum_s \omega_{3s} U^P\left(c_{3s}^{P,run}\right) + (1-q)\left[\sum_s \omega_{3s} U^P\left(c_{3s}^{P,no\text{-}run}\right)\right]$$

subject to the following constraints:

$$c_1^P + I^P \leq e_1^P$$

$$c_{3s}^{P,no\text{-}run} \leq \max\left[A_{3s} F\left(I + I^P\right) - I(1+r^I), 0\right] + e_{3s}^P$$

$$c_{3s}^{P,run} \leq \xi \cdot I^P + e_{3s}^P$$

Timeline

# R's Optimization problem

$$\bar{U}^R = U^R\left(c_1^R\right) + q\left[\theta \cdot U^R\left(c_{2/3}^{R,run,paid}\right) + (1-\theta)\, U^R\left(c_{2/3}^{R,run,unpaid}\right)\right]$$
$$+ (1-q)\left[\delta \cdot U^R\left(c_2^{R,i,no\text{-}run}\right) + (1-\delta)\cdot \sum_s \omega_{3s} U^R\left(c_{3s}^{R,p,no\text{-}run}\right)\right]$$

subject to the following constraints:

$$c_1^R + P_{eq}^R x_{eq}^R + D^R + LIQ_1^R \leq e_1^R$$

<u>No bank-run</u>

$$\text{If impatient:}\quad c_2^{R,i,no\text{-}run} \leq (1+r_2^D)D^R + LIQ_1^R + P_{sec}x_{eq}^R + e_2^R$$
$$P_{sec}x_{sec}^R + LIQ_2^R \leq LIQ_1^R + P_{sec}x_{eq}^R + e_2^R$$
$$\text{If patient:}\quad c_{3s}^{R,p,no\text{-}run} \leq x_{sec}^R DPS_{3s} + V_{3s}^D D^R(1+r_3^D) + LIQ_2^R$$

$DPS_{3s}$ are the dividends per share from holding equity in the bank

<u>Bank-run</u>

$$\text{If lucky:}\quad c_{2/3}^{R,run,paid} \leq (1+r_2^D)D^R + LIQ_1^R + e_2^R$$
$$\text{If unlucky:}\quad c_{2/3}^{R,run,unpaid} \leq LIQ_1^R + e_2^R$$

# B's Optimization problem

$$\max \bar{U}^B = U^B\left(c_1^B\right) + q \cdot \left[\theta \sum_s \omega_{3s} U^B\left(c_{3s}^{B,run,paid}\right) + (1-\theta)\sum_s \omega_{3s} U^B\left(c_{3s}^{B,run,unpaid}\right)\right] + (1-q)\left[\sum_s \omega_{3s} U_{3s}^B\left(c_{3s}^{B,no\text{-}run}\right)\right]$$

subject to the following constraints:

$(t = 1)$

Managing own wealth: $c_1^B + P_{eq}^B x_{eq}^B + D^B + LIQ_1^B \leq e_1^B$

Managing the bank: $I + LIQ_1 \leq P_{eq}^B x_{eq}^B + D^B + P_{eq}^B x_{eq}^R + D^R + E^B$

$(t = 2, \textit{no-run})$

Managing own wealth: $P_{sec} x_{sec}^B + LIQ_2^B \leq LIQ_1^B + P_{sec} x_{eq}^B$

Managing the bank: $\delta \cdot D^R(1 + r_2^D) + LIQ_2 \leq LIQ_1$

$(t = 2, \textit{run})$

Serve $\theta$% of depositors: $\theta \cdot D^R(1 + r_2^D) = LIQ_1 + \xi \cdot I$

Timeline

$(t=3, \textit{no-run})$

$$c_{3s}^{B,\textit{no-run}} \leq \frac{E^B + x^B_{sec}}{E^B + x^R_{eq} + x^B_{eq}} \max\left[V^I_{3s} I(1+r^I) + LIQ_2 - \left((1-\delta)D^R + D^B\right)(1+r^D_3), 0\right]$$
$$+ V^D_{3s} D^B (1+r^D_3) + LIQ^B_2 + e^B_{3s}$$

$(t=3, \textit{run})$

$$c_{3s}^{B,\textit{run},\textit{paid}} \leq D^B(1+r^D_2) + LIQ^B_1 + e^B_{3s}$$
$$c_{3s}^{B,\textit{run},\textit{unpaid}} \leq LIQ^B_1 + e^B_{3s}$$

$$\text{where} \qquad V^D_{3s} = \min\left[1, \frac{V^I_{3s} I(1+r^I) + LIQ_2}{\left((1-\delta)D^R + D^B\right)(1+r^D_3)}\right]$$

- We choose $e^B_1$ low enough such that $B$ does not choose to deposit in the bank, $D^B = 0$, or hoard liquidity, $LIQ^B_1 = 0$
- Finally, the incentive compatibility constraint such that patient depositors prefer to wait in normal times

$$\sum_s \omega_{3s} U^R\left(x^R_{sec}\left(DPS_{3s} - P_{sec}\right) + V^D_{3s} D^R (1+r^D_3) + LIQ^R_1 + P_{sec} x^R_{eq} + e^R_2\right) \geq$$
$$\sum_s \omega_{3s} U^R\left(x^{R'}_{sec}\left(DPS_{3s} - P_{sec}\right) + D^R (1+r^D_2) + LIQ^R_1 + P_{sec} x^R_{eq} + e^R_2\right)$$

Timeline

# Generic properties of the competitive equilibrium

- P will not issue equity; R prefers equity in B to equity in P
- B never chooses to buy more equity in the bank
  - No gain from providing more insurance to R
- B ignores the effect of defaults on depositors due to limited liability: Creates a motive for excessive risk-taking
- Excessive leverage increases the probability of a **run**, which makes both deposits and equity less attractive to R: Creates the possibility of under-investment
- Over-investment or under-investment (relative to a constrained planner) are both possible in equilibrium

# Competitive Equilibrium

| | Competitive Equilibrium |
|---|---|
| Investment | 2.55 |
| Capital Ratio | 0.15 |
| Liquidity Ratio | 0.21 |
| Probability of bank-run | 0.11 |
| P's utility | -1.70 |
| R's utility | -0.21 |
| B's utility | -1.83 |

# What is the Role of the Bank?

- The bank provides three services:
  1. Provides liquidity insurance for impatient consumers, since agents cannot hedge their idiosyncratic liquidity shocks ex-ante
  2. Creates both debt and equity claims potentially improving the saving options for R, since agents cannot fully hedge period 3 aggregate uncertainty
  3. Expands credit available to P relative to when R must lend directly
- Financial intermediation improves risk-sharing and expands investment, but creates the potential for risk shifting by B & P due to limited liability
- Two externalities:
  1. B fails to recognize that taking more risk will raise its cost of funding
  2. B does not internalize how her risk taking changes the odds of a run

Modigliani-Miller

# Individually optimal deposit taking and lending by the bank

- The first-order condition with respect to lending by the bank is:

$$-\psi_1^B + \frac{E^B + x_{sec}^B}{E^B + x_{eq}^R + x_{eq}^B} \sum_{s \notin s^D} \lambda_{3s}^{B,no\text{-}run} V_{3s}^I (1 + r^I) = 0,$$

- The first-order condition with respect to deposit taking by the bank is:

$$\psi_1^B \left(1 - \delta(1 + r_2^D)\right) - (1 - \delta) \frac{E^B + x_{sec}^B}{E^B + x_{eq}^R + x_{eq}^B} \sum_{s \notin s^D} \lambda_{3s}^{B,no\text{-}run} (1 + r_3^D) = 0.$$

- Combining these two optimality conditions we get:

$$\sum_{s \notin s^D} (1 - q) \cdot \omega_{3s} U^{B\,\prime} (c_{3s}^{B,no\text{-}run}) \left[ V_{3s}^I (1 + r^I) - \frac{1 - \delta}{1 - \delta(1 + r_2^D)} (1 + r_3^D) \right] = 0$$

# Externality from risk-taking

$$\sum_{s \notin s^D} (1-q) \cdot \omega_{3s} U^{B\,\prime}(c_{3s}^{B,no\text{-}run}) \left[ V_{3s}^{I}(1+r^{I}) - \frac{1-\delta}{1-\delta(1+r_2^D)}(1+r_3^D) \right] = 0$$

- This equation implies that the banks takes on sufficient risk and leverage so that it makes losses in the medium risk state of the world
- This risk-shifting takes place because the banks ignore the consequences of its investment decision in the bankruptcy state $(V_{3b}^{I}(1+r^{I}) - (1+r^{D}))$
- But, $R$ takes this into consideration and charges a higher deposit rate:

$$-\lambda_1^R + \lambda_2^{R,i,no\text{-}run}(1+r_2^D) + \lambda_2^{R,run,paid}(1+r_2^D) + \sum_{s} \lambda_{3s}^{R,p,no\text{-}run} V_{3s}^{D}(1+r_3^D) = 0$$

# Externality from bank-runs

- Insight from Goldstein-Pauzner (2005) Global Games approach to bank-runs:
  - The probability of a bank run is a decreasing function of the proportion of depositors that can be sequentially served early before the bank goes bankrupt, i.e the value of bank assets at time 2 relative to the total amount of deposits owed if everyone runs
- We assume that the probability of a bank-run is $q = \left( \max \left[ 1 - \frac{LIQ_1 + \xi \cdot I}{D^R(1+r_2^D)}, 0 \right] \right)^2 = \left( \max \left[ 1 - \frac{LR + \xi}{(1+LR-CR)(1+r_2^D)}, 0 \right] \right)^2$, where $LR = \frac{LIQ_1}{I}$, $CR = \frac{EQ}{I}$ and $\xi$ is the liquidation value of risky investment
- Under this specification $q$ decreases for higher liquidity and capital ratios, higher $\xi$ and lower $r_2^D$
- Note that for $\frac{LIQ_1 + \xi \cdot I}{D^R(1+r_2^D)} \geq 1$, $q$ is always zero irrespective of the assumed functional form

Global Games

# Constrained Social Planner

- Internalizes

$$q = \left( \max \left[ 1 - \frac{LIQ_1 + \xi \cdot I}{D^R(1 + r_2^D)}, 0 \right] \right)^2$$

- Recognizes that the equation for $r_3^D$:

$$-\lambda_1^R + \lambda_2^{R,i,no\text{-}run}(1 + r_2^D) + \lambda_2^{R,run,paid}(1 + r_2^D) + \sum_s \lambda_{3s}^{R,p,no\text{-}run} V_{3s}^D (1 + r_3^D) = 0,$$

and the combined optimality conditions for deposit taking and lending by the bank:

$$\sum_{s \notin s^D} (1 - q) \cdot \omega_{3s} U^{B\,\prime}(c_{3s}^{B,no\text{-}run}) \left[ V_{3s}^I (1 + r^I) - \frac{1 - \delta}{1 - \delta(1 + r_2^D)} (1 + r_3^D) \right] \geq 0,$$

are jointly determined.

# Extreme regulatory alternative: Unlimited Liability

- Bounds lending to P to be below his endowment (”natural debt limit”)
- Bounds deposits to be less than P’s repayment and B’s endowment
- Greatly reduces risk-taking, shrinking lending to P, leaving him worse off
- Taking away the default option can make B worse off, though she gains from eliminating the run
- R gets safer savings, but earns a much lower return. Also, his ability to smooth consumption is greatly reduced and he is typically worse off

# Limited vs. Unlimited Liability

| | Competitive Equilibrium | Unlimited Liability |
|---|---|---|
| Investment | 2.55 | 0.31 |
| Capital Ratio | 0.15 | 0.65 |
| Liquidity Ratio | 0.21 | 0.09 |
| Probability of bank-run | 0.11 | 0.00 |
| P's utility | -1.70 | -1.72 |
| R's utility | -0.21 | -0.21 |
| B's utility | -1.83 | -1.85 |

## Calibrated example with over-investment ($w^P = 0.35$, $w^R = 0.35$)

| | Competitive Equilibrium | Unlimited Liability | Constrained Planner |
|---|---|---|---|
| Investment | 2.55 | 0.31 | 2.49 |
| Capital Ratio | 0.15 | 0.65 | 0.49 |
| Liquidity Ratio | 0.21 | 0.09 | 0.13 |
| Probability of bank-run | 0.11 | 0.00 | 0.00 |
| P's utility | -1.70 | -1.72 | -1.67 |
| R's utility | -0.21 | -0.21 | -0.20 |
| B's utility | -1.83 | -1.85 | -1.80 |
| Social Welfare | -1.00 | -1.02 | -0.98 |

# Planning outcomes

Table: % Change in Social Welfare: Constrained Planner vs. Competitive Equilibrium

| | | $w^R$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | *0.100* | *0.200* | *0.300* | *0.400* | *0.500* | *0.600* | *0.700* | *0.800* |
| | *0.100* | 6.77% | 5.43% | 4.10% | 2.77% | 2.05% | 2.08% | 2.13% | 2.21% |
| | *0.200* | 5.79% | 4.44% | 3.10% | 2.02% | 2.05% | 2.10% | 2.19% | - |
| | *0.300* | 4.82% | 3.47% | 2.12% | 2.02% | 2.07% | 2.18% | - | - |
| $w^P$ | *0.400* | 3.86% | 2.51% | 1.99% | 2.05% | 2.17% | - | - | - |
| | *0.500* | 2.92% | 1.95% | 2.03% | 2.17% | - | - | - | - |
| | *0.600* | 1.92% | 2.01% | 2.18% | - | - | - | - | - |
| | *0.700* | 2.01% | 2.22% | - | - | - | - | - | - |
| | *0.800* | 2.31% | - | - | - | - | - | - | - |

# Run risk

Table: Percentage points difference in the probability of a bank-run: Constrained Planner vs. Competitive Equilibrium

| | | $w^R$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | *0.100* | *0.200* | *0.300* | *0.400* | *0.500* | *0.600* | *0.700* | *0.800* |
| | *0.100* | -7.30% | -7.47% | -7.65% | -7.81% | -10.86% | -10.93% | -10.93% | -10.93% |
| | *0.200* | -6.81% | -6.97% | -7.14% | -10.84% | -10.92% | -10.93% | -10.93% | - |
| | *0.300* | -6.30% | -6.46% | -6.61% | -10.92% | -10.93% | -10.93% | - | - |
| $w^P$ | *0.400* | -5.78% | -5.93% | -10.91% | -10.93% | -10.93% | - | - | - |
| | *0.500* | -5.25% | -10.91% | -10.93% | -10.93% | - | - | - | - |
| | *0.600* | -10.90% | -10.93% | -10.93% | - | - | - | - | - |
| | *0.700* | -10.93% | -10.93% | - | - | - | - | - | - |
| | *0.800* | -10.93% | - | - | - | - | - | - | - |

# Planner's preferred capital ratios

Table: Percentage points difference in Capital Ratios: Constrained Planner vs. Competitive Equilibrium

| | | $w^R$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | *0.100* | *0.200* | *0.300* | *0.400* | *0.500* | *0.600* | *0.700* | *0.800* |
| | *0.100* | -1.77% | -1.53% | -1.27% | -1.04% | 33.43% | 34.66% | 35.23% | 35.23% |
| | *0.200* | -2.35% | -2.17% | -1.96% | 33.24% | 34.55% | 35.23% | 35.23% | - |
| | *0.300* | -2.87% | -2.72% | -2.57% | 34.43% | 35.23% | 35.23% | - | - |
| $w^P$ | *0.400* | -3.34% | -3.21% | 34.30% | 35.23% | 35.23% | - | - | - |
| | *0.500* | -3.75% | 34.16% | 35.23% | 35.23% | - | - | - | - |
| | *0.600* | 34.00% | 35.23% | 35.23% | - | - | - | - | - |
| | *0.700* | 35.23% | 35.23% | - | - | - | - | - | - |
| | *0.800* | 35.23% | - | - | - | - | - | - | - |

# Planner's preferred liquidity ratios

Table: Percentage points difference in Liquidity Ratios: Constrained Planner vs. Competitive Equilibrium

| | | $w^R$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | *0.100* | *0.200* | *0.300* | *0.400* | *0.500* | *0.600* | *0.700* | *0.800* |
| $w^P$ | *0.100* | 85.66% | 89.42% | 93.70% | 97.64% | -8.36% | -8.66% | -8.81% | -8.81% |
| | *0.200* | 76.10% | 79.12% | 82.47% | -8.31% | -8.64% | -8.81% | -8.81% | - |
| | *0.300* | 67.60% | 70.07% | 72.65% | -8.61% | -8.81% | -8.81% | - | - |
| | *0.400* | 60.00% | 62.06% | -8.58% | -8.81% | -8.81% | - | - | - |
| | *0.500* | 53.18% | -8.54% | -8.81% | -8.81% | - | - | - | - |
| | *0.600* | -8.50% | -8.81% | -8.81% | - | - | - | - | - |
| | *0.700* | -8.81% | -8.81% | - | - | - | - | - | - |
| | *0.800* | -8.81% | - | - | - | - | - | - | - |

Deposit rate

Intermediation spread

# Over- versus under-investment

Table: % Change in Investment: Constrained Planner vs. Competitive Equilibrium

| | | $w^R$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | *0.100* | *0.200* | *0.300* | *0.400* | *0.500* | *0.600* | *0.700* | *0.800* |
| | *0.100* | -39.66% | -40.71% | -41.87% | -42.86% | -2.84% | -2.59% | -1.18% | 2.28% |
| | *0.200* | -36.80% | -37.73% | -38.73% | -2.91% | -2.62% | -0.50% | 3.32% | - |
| | *0.300* | -34.04% | -34.86% | -35.69% | -2.64% | 0.36% | 4.63% | - | - |
| $w^P$ | *0.400* | -31.36% | -32.10% | -2.68% | 1.50% | 6.32% | - | - | - |
| | *0.500* | -28.77% | -2.71% | 3.07% | 8.44% | - | - | - | - |
| | *0.600* | -2.74% | 5.33% | 11.74% | - | - | - | - | - |
| | *0.700* | 9.15% | 16.38% | - | - | - | - | - | - |
| | *0.800* | 23.89% | - | - | - | - | - | - | - |

Deposit rate

Intermediation spread

# P's Welfare Under Different Planning Allocations

Table: % Change in P's Welfare: Constrained Planner vs. Competitive Equilibrium

| | | $w^R$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | *0.100* | *0.200* | *0.300* | *0.400* | *0.500* | *0.600* | *0.700* | *0.800* |
| | *0.100* | -0.81% | -0.86% | -0.92% | -0.97% | 1.89% | 1.91% | 1.97% | 2.12% |
| | *0.200* | -0.68% | -0.72% | -0.76% | 1.88% | 1.91% | 2.00% | 2.16% | - |
| | *0.300* | -0.58% | -0.61% | -0.64% | 1.91% | 2.04% | 2.21% | - | - |
| $w^P$ | *0.400* | -0.49% | -0.51% | 1.91% | 2.09% | 2.28% | - | - | - |
| | *0.500* | -0.42% | 1.90% | 2.15% | 2.35% | - | - | - | - |
| | *0.600* | 1.90% | 2.24% | 2.48% | - | - | - | - | - |
| | *0.700* | 2.39% | 2.64% | - | - | - | - | - | - |
| | *0.800* | 2.89% | - | - | - | - | - | - | - |

Deposit rate Investment Intermediation spread

# R's Welfare Under Different Planning Allocations

Table: % Change in R's Welfare: Constrained Planner vs. Competitive Equilibrium

| | | $w^R$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | *0.100* | *0.200* | *0.300* | *0.400* | *0.500* | *0.600* | *0.700* | *0.800* |
| | *0.100* | -4.30% | -4.28% | -4.26% | -3.82% | 2.20% | 2.24% | 2.28% | 2.34% |
| | *0.200* | -4.37% | -4.35% | -4.32% | 2.26% | 2.23% | 2.30% | 2.34% | - |
| | *0.300* | -4.44% | -4.42% | -4.25% | 2.23% | 2.31% | 2.35% | - | - |
| $w^P$ | *0.400* | -4.52% | -4.49% | 2.23% | 2.33% | 2.34% | - | - | - |
| | *0.500* | -4.60% | 2.22% | 2.34% | 2.31% | - | - | - | - |
| | *0.600* | 2.22% | 2.34% | 2.24% | - | - | - | - | - |
| | *0.700* | 2.24% | 2.06% | - | - | - | - | - | - |
| | *0.800* | 1.53% | - | - | - | - | - | - | - |

Deposit rate Investment Intermediation spread

# B's Welfare Under Different Planning Allocations

Table: % Change in B's Welfare: Constrained Planner vs. Competitive Equilibrium

| | | $w^R$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | *0.100* | *0.200* | *0.300* | *0.400* | *0.500* | *0.600* | *0.700* | *0.800* |
| | *0.100* | 9.11% | 9.11% | 9.11% | 8.78% | 1.90% | 1.84% | 1.68% | 1.32% |
| | *0.200* | 9.09% | 9.10% | 9.10% | 1.91% | 1.84% | 1.61% | 1.21% | - |
| | *0.300* | 9.06% | 9.07% | 8.97% | 1.85% | 1.52% | 1.07% | - | - |
| $w^P$ | *0.400* | 9.02% | 9.03% | 1.85% | 1.41% | 0.87% | - | - | - |
| | *0.500* | 8.97% | 1.86% | 1.24% | 0.63% | - | - | - | - |
| | *0.600* | 1.87% | 0.99% | 0.20% | - | - | - | - | - |
| | *0.700* | 0.57% | -0.45% | - | - | - | - | - | - |
| | *0.800* | -1.59% | - | - | - | - | - | - | - |

Deposit rate Investment Intermediation spread

# Summary from Planner's Allocations

Three basic configurations:

1. Raise liquidity to control a run without preventing the bank from gambling (purple)
2. Raise bank equity to control a run and reduce investment to manage excess risk-taking (blue)
3. Raise bank equity to control a run and raise investment to help P or R (green)

# Regulatory tools

- Capital requirements
- Liquidity requirements
- Deposit insurance
- Loan to value requirements
- Dividend taxes
- Optimal combinations

# Capital Regulation

- More stable funding decreases the probability of a bank-run
- Force lower leverage, so the bank cannot fully exploit its limited liability
- But, fewer deposits require less liquidity to serve early withdrawals $\rightarrow$ creates extra lending capacity

| | Competitive Equilibrium | Capital Regulation |
|---|---|---|
| $I$ | 2.548 | 2.782 |
| $CR$ | 14.77% | 50.00% |
| $LR$ | 21.31% | 12.50% |
| $q$ | 10.93% | 0.00% |
| $U^P$ | -1.69675 | -1.65626 |
| $U^R$ | -0.20559 | -0.20097 |
| $U^B$ | -1.83416 | -1.82463 |

# Higher required liquidity

- Substitutes safe assets for risky ones, but does not necessarily reduce the risk of a run: The probability of a run can be written as $q = \left(1 - \delta \frac{1+\xi \frac{1}{LR}}{1 - \frac{LIQ_2}{LIQ_1}}\right)^2$
- Creates incentive to use more deposit finance, and the bank does not adjust its required rate of return
- The bank will cut lending to preserve its rate of return

| | Competitive Equilibrium | Liquidity Regulation |
|---|---|---|
| $I$ | 2.548 | 2.419 |
| $CR$ | 14.77% | 12.86% |
| $LR$ | 21.31% | 28.31% |
| $q$ | 10.93% | 10.35% |
| $U^P$ | -1.69675 | -1.69825 |
| $U^R$ | -0.20559 | -0.20499 |
| $U^B$ | -1.83416 | -1.83654 |

# Deposit Insurance

- Consider a policy that guarantees deposit repayment even in states that the bank is not solvent and funds this by levying lump-sum taxes
- Zero probability of a bank run, but also eliminates market discipline for excessive risk-taking
- Still a Pareto improvement over the competitive equilibrium

| | Competitive Equilibrium | Deposit Insurance |
|---|---|---|
| $I$ | 2.548 | 2.815 |
| $CR$ | 14.77% | 10.49% |
| $LR$ | 21.31% | 22.38% |
| $q$ | 10.93% | 0.00% |
| $U^P$ | -1.69675 | -1.65545 |
| $U^R$ | -0.20559 | -0.20271 |
| $U^B$ | -1.83416 | -1.82042 |

# Lower loan to value requirements

- Forces P to have some skin in the game, reduces the amount he can borrow
- Raises loan and deposit repayments in the medium and bad state
- B ignores the effect on the bad state
- R increases deposits
- B substitutes toward safe assets, but not enough to reduce the run probability

| | Competitive Equilibrium | LTV Regulation |
|---|---|---|
| $I$ | 2.548 | 2.505 |
| $CR$ | 14.77% | 7.98% |
| $LR$ | 21.31% | 23.00% |
| $LTV$ | 100% | 99.30% |
| $q$ | 10.93% | 13.34% |
| $U^P$ | -1.69675 | -1.70165 |
| $U^R$ | -0.20559 | -0.20858 |
| $U^B$ | -1.83416 | -1.84230 |

# Dividend taxes

- Pushes R to reduce equity purchase and increase deposits (pushing down the deposit rate)
- Allows B to gamble more
- Does not help with the run risk

| | Competitive Equilibrium | Dividend Tax |
|---|---|---|
| $I$ | 2.548 | 2.503 |
| $CR$ | 14.77% | 7.98% |
| $LR$ | 21.31% | 23.00% |
| $\tau_{Div}$ | 0% | 45% |
| $q$ | 10.93% | 13.34% |
| $U^P$ | -1.69675 | -1.70542 |
| $U^R$ | -0.20559 | -0.20764 |
| $U^B$ | -1.83416 | -1.82595 |

# Optimal Regulation

Three combinations depending on the planner's preferences:

- Liquidity regulation, dividend tax and tax on the safe asset
- Capital regulation, dividend tax and tax on the safe asset
  - Alternatively, capital and liquidity regulations combined
- Capital regulation and deposit insurance

# Liquidity regulation, dividend tax and tax on the safe asset

Table: Optimal Regulation for $w^P = w^R = 0.2$, $w^B = 0.6$

| | Competitive Equilibrium | Constrained Planner | Liquidity Regulation | Optimal Mix |
|---|---|---|---|---|
| $I$ | 2.548 | 1.587 | 1.776 | 1.587 |
| $D^R$ | 2.715 | 2.981 | 2.869 | 2.981 |
| $x_{eq}^R$ | 0.176 | 0.000 | 0.098 | 0.000 |
| $LIQ_1$ | 0.543 | 1.594 | 1.391 | 1.594 |
| $LIQ_2/LIQ_1$ | 0.000 | 0.626 | 0.587 | 0.626 |
| $r^d$ | 0.570 | 0.047 | 0.526 | 0.047 |
| $q$ | 0.109 | 0.040 | 0.042 | 0.040 |
| $CR$ | 0.148 | 0.126 | 0.168 | 0.126 |
| $LR$ | 0.213 | 1.004 | 0.783 | 1.004 |
| $\tau_{Div}$ | - | - | - | 0.358 |
| $\tau_{LIQ}$ | - | - | - | 0.018 |
| $U^P$ | -1.697 | -1.709 | -1.701 | -1.709 |
| $U^R$ | -0.206 | -0.215 | -0.202 | -0.215 |
| $U^B$ | -1.834 | -1.667 | -1.835 | -1.667 |
| $U^{sp}$ | -1.000 | -0.956 | -0.997 | -0.956 |

# Capital regulation and dividend tax vs. capital and liquidity regulations

Table: Optimal Regulation for $w^P = 0.2$, $w^R = 0.6$, $w^B = 0.2$

| | Competitive Equilibrium | Constrained Planner | Capital Regulation | Optimal Mix | Capital & Liquidity Regulation |
|---|---|---|---|---|---|
| $I$ | 2.548 | 2.536 | 2.782 | 2.536 | 2.435 |
| $D^R$ | 2.715 | 1.585 | 1.739 | 1.585 | 1.936 |
| $x^R_{eq}$ | 0.176 | 1.068 | 1.191 | 1.068 | 1.017 |
| $LIQ_1$ | 0.543 | 0.317 | 0.348 | 0.317 | 0.718 |
| $LIQ_2/LIQ_1$ | 0.000 | 0.000 | 0.000 | 0.000 | 0.461 |
| $r^d$ | 0.570 | 0.137 | 0.464 | 0.137 | 0.473 |
| $q$ | 0.109 | 0.000 | 0.000 | 0.000 | 0.000 |
| $CR$ | 0.148 | 0.500 | 0.500 | 0.500 | 0.500 |
| $LR$ | 0.213 | 0.125 | 0.125 | 0.125 | 0.295 |
| $\tau_{Div}$ | - | - | - | 0.439 | 0.000 |
| $\tau_{LIQ}$ | - | - | - | 0.487 | 0.000 |
| $U^P$ | -1.697 | -1.663 | -1.656 | -1.663 | -1.666 |
| $U^R$ | -0.206 | -0.201 | -0.201 | -0.201 | -0.200 |
| $U^B$ | -1.834 | -1.805 | -1.825 | -1.805 | -1.825 |
| $U^{sp}$ | -1.000 | -0.979 | -0.982 | -0.979 | -0.980 |

▸ CR & LR: Alternative weights

## Challenges of eliminating the run and limiting risk-taking

- Capital requirements can eliminate the run, but result in higher investment
- Deposit insurance eliminates the run, but it increases the incentives for risk-shifting
- A combination of capital requirements and dividend taxes can eliminate the run and tame risk taking, but it can violate the incentive compatibility constraint of patient depositors. Thus, it may also require a tax on liquid assets in order to yield the desired reduction in risk taking
- Capital and liquidity requirements together eliminate the run and reduce risk-taking, but also reduce the profits from intermediation and are harmful for the bankers
- Capital and loan-to-value requirements together can also eliminate the run and reduce risk-taking, but are harmful for the entrepreneur and reduce profits from intermediation

# Capital regulation and deposit insurance

Table: Optimal Regulation for $w^P = 0.6$, $w^R = 0.3$, $w^B = 0.1$

| | Competitive Equilibrium | Constrained Planner | Capital Regulation | Capital regulation & Deposit Insurance |
|---|---|---|---|---|
| $I$ | 2.548 | 2.848 | 2.782 | 2.896 |
| $D^R$ | 2.715 | 1.780 | 1.739 | 1.810 |
| $x_{eq}^R$ | 0.176 | 1.224 | 1.191 | 1.248 |
| $LIQ_1$ | 0.543 | 0.356 | 0.348 | 0.362 |
| $LIQ_2/LIQ_1$ | 0.000 | 0.000 | 0.000 | 0.000 |
| $r^d$ | 0.570 | 0.557 | 0.464 | 0.307 |
| $q$ | 0.109 | 0.000 | 0.000 | 0.000 |
| $CR$ | 0.148 | 0.500 | 0.500 | 0.500 |
| $LR$ | 0.213 | 0.125 | 0.125 | 0.125 |
| $U^P$ | -1.697 | -1.655 | -1.656 | -1.654 |
| $U^R$ | -0.206 | -0.201 | -0.201 | -0.202 |
| $U^B$ | -1.834 | -1.830 | -1.825 | -1.819 |
| $U^{sp}$ | -1.000 | -0.978 | -0.982 | -0.978 |

# Conclusions

- Lots of insights from this approach, but must
  - use GE models, with forward looking agents, and allow banks to provide multiple services
- Regulations that reduce the risk of a run can potentially generate Pareto improvements
- Preventing the excessive gambling is harder because of counterbalancing effects on different agents
- Allocational consequences of different regulations creates incentives for regulatory arbitrage and to lobby

$\boxed{\text{BACK-UP SLIDES}}$

# Aggregating B & R into a single agent

## Proposition

Is possible under very special conditions

- Identical HARA utility functions
- R has suficient wealth so that he buys equity in B
- ALL HOUSEHOLDS R ARE PATIENT
- NO BANKRUPTCY

- With bankruptcy, because B has limited liability, her valuations and R's diverge and aggregation fails even with CAPM utilities
- With impatient households R, valuations of B and R diverge as well
- Only way that capital structure is irrelevant (i.e. MM holds) is when aggregation of B & R obtains

Return

Table: Deposit Rate in Planner's solution

| | | $w^R$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | *0.100* | *0.200* | *0.300* | *0.400* | *0.500* | *0.600* | *0.700* | *0.800* |
| | *0.100* | 0.05 | 0.04 | 0.04 | 0.07 | 0.08 | 0.08 | 0.12 | 0.22 |
| | *0.200* | 0.05 | 0.05 | 0.05 | 0.08 | 0.08 | 0.14 | 0.26 | - |
| | *0.300* | 0.05 | 0.05 | 0.06 | 0.08 | 0.16 | 0.30 | - | - |
| $w^P$ | *0.400* | 0.06 | 0.06 | 0.08 | 0.20 | 0.36 | - | - | - |
| | *0.500* | 0.06 | 0.08 | 0.25 | 0.43 | - | - | - | - |
| | *0.600* | 0.08 | 0.32 | 0.56 | - | - | - | - | - |
| | *0.700* | 0.45 | 0.74 | - | - | - | - | - | - |
| | *0.800* | 1.05 | - | - | - | - | - | - | - |

Return to LR

Table: Percentage points difference in Intermediation Spread: Constrained Planner vs. Competitive Equilibrium

| | | $w^R$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | *0.100* | *0.200* | *0.300* | *0.400* | *0.500* | *0.600* | *0.700* | *0.800* |
| | *0.100* | 81.11% | 82.33% | 83.68% | 82.30% | 50.31% | 50.41% | 46.00% | 33.47% |
| | *0.200* | 77.94% | 78.95% | 80.07% | 50.29% | 50.40% | 43.59% | 29.58% | - |
| | *0.300* | 75.00% | 75.86% | 75.85% | 50.39% | 40.48% | 24.59% | - | - |
| $w^P$ | *0.400* | 72.27% | 73.02% | 50.38% | 36.34% | 17.99% | - | - | - |
| | *0.500* | 69.73% | 50.37% | 30.55% | 9.85% | - | - | - | - |
| | *0.600* | 50.36% | 21.96% | -4.38% | - | - | - | - | - |
| | *0.700* | 7.97% | -25.01% | - | - | - | - | - | - |
| | *0.800* | -58.95% | - | - | - | - | - | - | - |

Return to LR

Table: Deposit Rate in Planner's solution

| | | $w^R$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | *0.100* | *0.200* | *0.300* | *0.400* | *0.500* | *0.600* | *0.700* | *0.800* |
| | *0.100* | 0.05 | 0.04 | 0.04 | 0.07 | 0.08 | 0.08 | 0.12 | 0.22 |
| | *0.200* | 0.05 | 0.05 | 0.05 | 0.08 | 0.08 | 0.14 | 0.26 | - |
| | *0.300* | 0.05 | 0.05 | 0.06 | 0.08 | 0.16 | 0.30 | - | - |
| $w^P$ | *0.400* | 0.06 | 0.06 | 0.08 | 0.20 | 0.36 | - | - | - |
| | *0.500* | 0.06 | 0.08 | 0.25 | 0.43 | - | - | - | - |
| | *0.600* | 0.08 | 0.32 | 0.56 | - | - | - | - | - |
| | *0.700* | 0.45 | 0.74 | - | - | - | - | - | - |
| | *0.800* | 1.05 | - | - | - | - | - | - | - |

Return to Investment

Table: Percentage points difference in Intermediation Spread: Constrained Planner vs. Competitive Equilibrium

| | | $w^R$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | *0.100* | *0.200* | *0.300* | *0.400* | *0.500* | *0.600* | *0.700* | *0.800* |
| | *0.100* | 81.11% | 82.33% | 83.68% | 82.30% | 50.31% | 50.41% | 46.00% | 33.47% |
| | *0.200* | 77.94% | 78.95% | 80.07% | 50.29% | 50.40% | 43.59% | 29.58% | - |
| | *0.300* | 75.00% | 75.86% | 75.85% | 50.39% | 40.48% | 24.59% | - | - |
| $w^P$ | *0.400* | 72.27% | 73.02% | 50.38% | 36.34% | 17.99% | - | - | - |
| | *0.500* | 69.73% | 50.37% | 30.55% | 9.85% | - | - | - | - |
| | *0.600* | 50.36% | 21.96% | -4.38% | - | - | - | - | - |
| | *0.700* | 7.97% | -25.01% | - | - | - | - | - | - |
| | *0.800* | -58.95% | - | - | - | - | - | - | - |

Return to Investment

Table: Deposit Rate in Planner's solution

| | | $w^R$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 0.100 | 0.200 | 0.300 | 0.400 | 0.500 | 0.600 | 0.700 | 0.800 |
| | 0.100 | 0.05 | 0.04 | 0.04 | 0.07 | 0.08 | 0.08 | 0.12 | 0.22 |
| | 0.200 | 0.05 | 0.05 | 0.05 | 0.08 | 0.08 | 0.14 | 0.26 | - |
| | 0.300 | 0.05 | 0.05 | 0.06 | 0.08 | 0.16 | 0.30 | - | - |
| $w^P$ | 0.400 | 0.06 | 0.06 | 0.08 | 0.20 | 0.36 | - | - | - |
| | 0.500 | 0.06 | 0.08 | 0.25 | 0.43 | - | - | - | - |
| | 0.600 | 0.08 | 0.32 | 0.56 | - | - | - | - | - |
| | 0.700 | 0.45 | 0.74 | - | - | - | - | - | - |
| | 0.800 | 1.05 | - | - | - | - | - | - | - |

Return to P's welfare

Table: % Change in Investment: Constrained Planner vs. Competitive Equilibrium

| | | $w^R$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | *0.100* | *0.200* | *0.300* | *0.400* | *0.500* | *0.600* | *0.700* | *0.800* |
| | *0.100* | -39.66% | -40.71% | -41.87% | -42.86% | -2.84% | -2.59% | -1.18% | 2.28% |
| | *0.200* | -36.80% | -37.73% | -38.73% | -2.91% | -2.62% | -0.50% | 3.32% | - |
| | *0.300* | -34.04% | -34.86% | -35.69% | -2.64% | 0.36% | 4.63% | - | - |
| $w^P$ | *0.400* | -31.36% | -32.10% | -2.68% | 1.50% | 6.32% | - | - | - |
| | *0.500* | -28.77% | -2.71% | 3.07% | 8.44% | - | - | - | - |
| | *0.600* | -2.74% | 5.33% | 11.74% | - | - | - | - | - |
| | *0.700* | 9.15% | 16.38% | - | - | - | - | - | - |
| | *0.800* | 23.89% | - | - | - | - | - | - | - |

Return to P's welfare

Table: Percentage points difference in Intermediation Spread: Constrained Planner vs. Competitive Equilibrium

| | | $w^R$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | *0.100* | *0.200* | *0.300* | *0.400* | *0.500* | *0.600* | *0.700* | *0.800* |
| | *0.100* | 81.11% | 82.33% | 83.68% | 82.30% | 50.31% | 50.41% | 46.00% | 33.47% |
| | *0.200* | 77.94% | 78.95% | 80.07% | 50.29% | 50.40% | 43.59% | 29.58% | - |
| | *0.300* | 75.00% | 75.86% | 75.85% | 50.39% | 40.48% | 24.59% | - | - |
| $w^P$ | *0.400* | 72.27% | 73.02% | 50.38% | 36.34% | 17.99% | - | - | - |
| | *0.500* | 69.73% | 50.37% | 30.55% | 9.85% | - | - | - | - |
| | *0.600* | 50.36% | 21.96% | -4.38% | - | - | - | - | - |
| | *0.700* | 7.97% | -25.01% | - | - | - | - | - | - |
| | *0.800* | -58.95% | - | - | - | - | - | - | - |

Return to P's welfare

Table: Deposit Rate in Planner's solution

| | | $w^R$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | *0.100* | *0.200* | *0.300* | *0.400* | *0.500* | *0.600* | *0.700* | *0.800* |
| | *0.100* | 0.05 | 0.04 | 0.04 | 0.07 | 0.08 | 0.08 | 0.12 | 0.22 |
| | *0.200* | 0.05 | 0.05 | 0.05 | 0.08 | 0.08 | 0.14 | 0.26 | - |
| | *0.300* | 0.05 | 0.05 | 0.06 | 0.08 | 0.16 | 0.30 | - | - |
| $w^P$ | *0.400* | 0.06 | 0.06 | 0.08 | 0.20 | 0.36 | - | - | - |
| | *0.500* | 0.06 | 0.08 | 0.25 | 0.43 | - | - | - | - |
| | *0.600* | 0.08 | 0.32 | 0.56 | - | - | - | - | - |
| | *0.700* | 0.45 | 0.74 | - | - | - | - | - | - |
| | *0.800* | 1.05 | - | - | - | - | - | - | - |

Return to R's welfare

Table: % Change in Investment: Constrained Planner vs. Competitive Equilibrium

| | | $w^R$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | *0.100* | *0.200* | *0.300* | *0.400* | *0.500* | *0.600* | *0.700* | *0.800* |
| | *0.100* | -39.66% | -40.71% | -41.87% | -42.86% | -2.84% | -2.59% | -1.18% | 2.28% |
| | *0.200* | -36.80% | -37.73% | -38.73% | -2.91% | -2.62% | -0.50% | 3.32% | - |
| | *0.300* | -34.04% | -34.86% | -35.69% | -2.64% | 0.36% | 4.63% | - | - |
| $w^P$ | *0.400* | -31.36% | -32.10% | -2.68% | 1.50% | 6.32% | - | - | - |
| | *0.500* | -28.77% | -2.71% | 3.07% | 8.44% | - | - | - | - |
| | *0.600* | -2.74% | 5.33% | 11.74% | - | - | - | - | - |
| | *0.700* | 9.15% | 16.38% | - | - | - | - | - | - |
| | *0.800* | 23.89% | - | - | - | - | - | - | - |

Return to R's welfare

Table: Percentage points difference in Intermediation Spread: Constrained Planner vs. Competitive Equilibrium

| | | $w^R$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | *0.100* | *0.200* | *0.300* | *0.400* | *0.500* | *0.600* | *0.700* | *0.800* |
| | *0.100* | 81.11% | 82.33% | 83.68% | 82.30% | 50.31% | 50.41% | 46.00% | 33.47% |
| | *0.200* | 77.94% | 78.95% | 80.07% | 50.29% | 50.40% | 43.59% | 29.58% | - |
| | *0.300* | 75.00% | 75.86% | 75.85% | 50.39% | 40.48% | 24.59% | - | - |
| $w^P$ | *0.400* | 72.27% | 73.02% | 50.38% | 36.34% | 17.99% | - | - | - |
| | *0.500* | 69.73% | 50.37% | 30.55% | 9.85% | - | - | - | - |
| | *0.600* | 50.36% | 21.96% | -4.38% | - | - | - | - | - |
| | *0.700* | 7.97% | -25.01% | - | - | - | - | - | - |
| | *0.800* | -58.95% | - | - | - | - | - | - | - |

Return to R's welfare

Table: Deposit Rate in Planner's solution

| | | $w^R$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | *0.100* | *0.200* | *0.300* | *0.400* | *0.500* | *0.600* | *0.700* | *0.800* |
| | *0.100* | 0.05 | 0.04 | 0.04 | 0.07 | 0.08 | 0.08 | 0.12 | 0.22 |
| | *0.200* | 0.05 | 0.05 | 0.05 | 0.08 | 0.08 | 0.14 | 0.26 | - |
| | *0.300* | 0.05 | 0.05 | 0.06 | 0.08 | 0.16 | 0.30 | - | - |
| $w^P$ | *0.400* | 0.06 | 0.06 | 0.08 | 0.20 | 0.36 | - | - | - |
| | *0.500* | 0.06 | 0.08 | 0.25 | 0.43 | - | - | - | - |
| | *0.600* | 0.08 | 0.32 | 0.56 | - | - | - | - | - |
| | *0.700* | 0.45 | 0.74 | - | - | - | - | - | - |
| | *0.800* | 1.05 | - | - | - | - | - | - | - |

Return to B's welfare

Table: % Change in Investment: Constrained Planner vs. Competitive Equilibrium

| | | $w^R$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | *0.100* | *0.200* | *0.300* | *0.400* | *0.500* | *0.600* | *0.700* | *0.800* |
| | *0.100* | -39.66% | -40.71% | -41.87% | -42.86% | -2.84% | -2.59% | -1.18% | 2.28% |
| | *0.200* | -36.80% | -37.73% | -38.73% | -2.91% | -2.62% | -0.50% | 3.32% | - |
| | *0.300* | -34.04% | -34.86% | -35.69% | -2.64% | 0.36% | 4.63% | - | - |
| $w^P$ | *0.400* | -31.36% | -32.10% | -2.68% | 1.50% | 6.32% | - | - | - |
| | *0.500* | -28.77% | -2.71% | 3.07% | 8.44% | - | - | - | - |
| | *0.600* | -2.74% | 5.33% | 11.74% | - | - | - | - | - |
| | *0.700* | 9.15% | 16.38% | - | - | - | - | - | - |
| | *0.800* | 23.89% | - | - | - | - | - | - | - |

Return to B's welfare

Table: Percentage points difference in Intermediation Spread: Constrained Planner vs. Competitive Equilibrium

| | | $w^R$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | *0.100* | *0.200* | *0.300* | *0.400* | *0.500* | *0.600* | *0.700* | *0.800* |
| | *0.100* | 81.11% | 82.33% | 83.68% | 82.30% | 50.31% | 50.41% | 46.00% | 33.47% |
| | *0.200* | 77.94% | 78.95% | 80.07% | 50.29% | 50.40% | 43.59% | 29.58% | - |
| | *0.300* | 75.00% | 75.86% | 75.85% | 50.39% | 40.48% | 24.59% | - | - |
| $w^P$ | *0.400* | 72.27% | 73.02% | 50.38% | 36.34% | 17.99% | - | - | - |
| | *0.500* | 69.73% | 50.37% | 30.55% | 9.85% | - | - | - | - |
| | *0.600* | 50.36% | 21.96% | -4.38% | - | - | - | - | - |
| | *0.700* | 7.97% | -25.01% | - | - | - | - | - | - |
| | *0.800* | -58.95% | - | - | - | - | - | - | - |

Return to B's welfare

# Timing

| t=1 | t=2 | t=3 |
|---|---|---|
| R chooses:<br>-How much to invest with P, B or in the riskless asset<br>-Whether to fund B with deposits or equity<br>- How much to consume this period | R learns whether he is impatient or not:<br>-If he is impatient, he withdraws his deposit and consumes<br>- If patient, he might run based on B's riskiness and consume whatever he can | If a run has not occurred, then there are 3 outcomes for P's project (High, Med, Low)<br><br>P repays all loans to R & B (or defaults) |
| B chooses:<br>-Whether to make deposits or to buy bank equity<br>-Whether to invest in the riskless asset<br>-Scale of the loan to P<br>-How much to consume this period | B chooses:<br>- How to service withdrawals, selling the riskless asset or liquidating loans<br><br>P learns if his loan is called by B | B repays deposits first (or defaults) and then pays pro-rata dividends on equity<br><br>All agents consume |
| P chooses:<br>- The scale of the risky investment<br>- How much to consume this period | | |

Return to P's problem

# Timing

| t=1 | t=2 | t=3 |
|---|---|---|
| R chooses:<br>-How much to invest with P, B or in the riskless asset<br>-Whether to fund B with deposits or equity<br>- How much to consume this period | R learns whether he is impatient or not:<br>-If he is impatient, he withdraws his deposit and consumes<br>- If patient, he might run based on B's riskiness and consume whatever he can | If a run has not occurred, then there are 3 outcomes for P's project (High, Med, Low)<br><br>P repays all loans to R & B (or defaults) |
| B chooses:<br>-Whether to make deposits or to buy bank equity<br>-Whether to invest in the riskless asset<br>-Scale of the loan to P<br>-How much to consume this period | B chooses:<br>- How to service withdrawals, selling the riskless asset or liquidating loans<br><br>P learns if his loan is called by B | B repays deposits first (or defaults) and then pays pro-rata dividends on equity<br><br>All agents consume |
| P chooses:<br>- The scale of the risky investment<br>- How much to consume this period | | |

Return to R's problem

# Timing

| t=1 | t=2 | t=3 |
|---|---|---|
| R chooses:<br> -How much to invest with P, B or in the riskless asset<br> -Whether to fund B with deposits or equity<br> - How much to consume this period | R learns whether he is impatient or not:<br> -If he is impatient, he withdraws his deposit and consumes<br> - If patient, he might run based on B's riskiness and consume whatever he can | If a run has not occurred, then there are 3 outcomes for P's project (High, Med, Low)<br><br>P repays all loans to R & B (or defaults) |
| B chooses:<br> -Whether to make deposits or to buy bank equity<br> -Whether to invest in the riskless asset<br> -Scale of the loan to P<br> -How much to consume this period | B chooses:<br> - How to service withdrawals, selling the riskless asset or liquidating loans<br><br>P learns if his loan is called by B | B repays deposits first (or defaults) and then pays pro-rata dividends on equity<br><br>All agents consume |
| P chooses:<br>- The scale of the risky investment<br>- How much to consume this period | | |

Return to B's problem

# Timing

| t=1 | t=2 | t=3 |
| --- | --- | --- |
| R chooses:<br>-How much to invest with P, B or in the riskless asset<br>-Whether to fund B with deposits or equity<br>- How much to consume this period | R learns whether he is impatient or not:<br>-If he is impatient, he withdraws his deposit and consumes<br>- If patient, he might run based on B's riskiness and consume whatever he can | If a run has not occurred, then there are 3 outcomes for P's project (High, Med, Low)<br><br>P repays all loans to R & B (or defaults) |
| B chooses:<br>-Whether to make deposits or to buy bank equity<br>-Whether to invest in the riskless asset<br>-Scale of the loan to P<br>-How much to consume this period | B chooses:<br>- How to service withdrawals, selling the riskless asset or liquidating loans<br><br>P learns if his loan is called by B | B repays deposits first (or defaults) and then pays pro-rata dividends on equity<br><br>All agents consume |
| P chooses:<br>- The scale of the risky investment<br>- How much to consume this period | | |

Return to B's problem

- Assume that the probability of the state of the world, which is realized at $t = 3$, is driven by a state variable $z_\tau$, $\tau \in \{1, 2\}$ and that $z_2 = z_1 + \eta$, where $\eta \sim U[-\bar{\eta}, \bar{\eta}]$
- We assume that $\eta$ is realized at the beginning of period 2, but it is not publicly revealed. Rather, each depositor obtains a signal $x_i = \eta + \epsilon_i$, where $\epsilon_i$ are small error terms that are independently and uniformly distributed over $[-\epsilon, \epsilon]$
- While all impatient depositors demand early withdrawal, patient ones need to compare the expected payoffs from going to the bank in period 2 or 3. The ex-post payoff of a patient agent from these two options depends on both $\eta$ and the proportion $m$ of agents demanding early withdrawal
- We are interested in a threshold equilibrium in which a patient depositor with signal $x_i$ withdraws his deposits at $t = 2$ when the signal is below a common threshold, i.e. $x_i \leq x^*$. Otherwise, he withdraws at $t = 3$. This implies also a threshold for the fundamental, i.e. a run will occur when $\eta \leq \eta^*$

$$\int_{m=\delta}^{\theta} \sum_s \omega_{3s} \left( z_1 + x^* + \epsilon \left( 1 - 2\frac{m-\delta}{1-\delta} \right) \right) U^R(c_{3s}^{R,\text{no-run},\text{wait}}) dm + \int_{m=\theta}^{1} \frac{\theta}{m} U^R(c_{3s}^{R,\text{run},\text{unpaid}}) dm =$$

$$\int_{m=\delta}^{\theta} \sum_s \omega_{3s} \left( z_1 + x^* + \epsilon \left( 1 - 2\frac{m-\delta}{1-\delta} \right) \right) U^R(c_{3s}^{R,\text{no-run},\text{withdraw}}) dm + \int_{m=\theta}^{1} \frac{\theta}{m} U^R(c_{3s}^{R,\text{run},\text{paid}}) dm$$

where $\theta = \frac{LIQ_1 + \xi \cdot l}{D^R(1 + r_2^D)}$

▸ Return to bank-runs

# Combining CR and LR for $w^P = w^R = 0.35$, $w^B = 0.3$

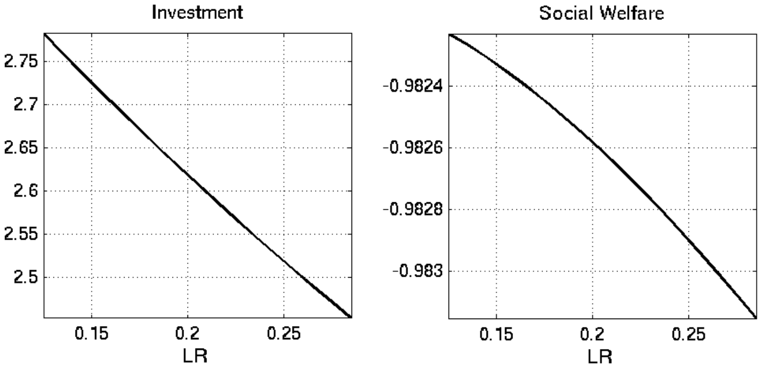


Figure: Risky investment (left) and social welfare (right) for stricter liquidity requirements under optimal capital regulation ($w^P = 0.35$, $w^R = 0.35$).

Return to optimal regulation