Liquidity Requirements and the Interbank Loan Market: An Experimental Investigation

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* The views expressed in this presentation are those of the authors and not necessarily those of the Federal Reserve Bank of Cleveland or the Federal Reserve System.

This Talk

- Tell you about bank liquidity regulations
- Tell you their history
- List costs and benefits
- Report an experiment that illustrates how some of these costs and benefits may come out of interbank market equilibrium behavior
- The experiment is exploratory. An early prototype.

Bank Liquidity Regulations

- Basel 3 creates two new liquidity regulations

- Liquidity Coverage Ratio (LCR)
  - Roughly, banks required to hold enough liquid assets (cash, Treasuries, corp debt) to meet a projected net cash outflow over a 30-day stressed period.
  - In U.S., applies mainly to large banks

- Net Stable Funding Ratio (NSFR)
  - (available amount of stable funding)/(required amount of stable funding) > 100%
  - ASF is liability measure. RSF is an asset measure. Different liabilities and assets get different weights.
    - ASF – equity 100% weight
    - RSF – cash 0% weight

- In U.S. – LCR implemented. NSFR not yet.

Benefits of Liquidity Regulations

- The financial crisis of 2007 and 2008
  - Big liquidity (and solvency) problems
  - Runs on some banks and investment banks

- Idea is that if banks hold more liquidity, runs and panics are less likely.

Costs of Liquidity Regulations

- Liquidity regulations reduce investment because banks make less loans and hold more cash and Treasuries

- Can create incentives to hoard liquidity during panics, making the panic worse
  - Idea is that when liquidity is scarce, banks less likely to lend to other banks to avoid violating their liquidity requirement, making liquidity even more scarce.
  - Milton Friedman's taxi stand story

National Banking Era (1863-1913)

- Gold standard, inelastic supply of currency

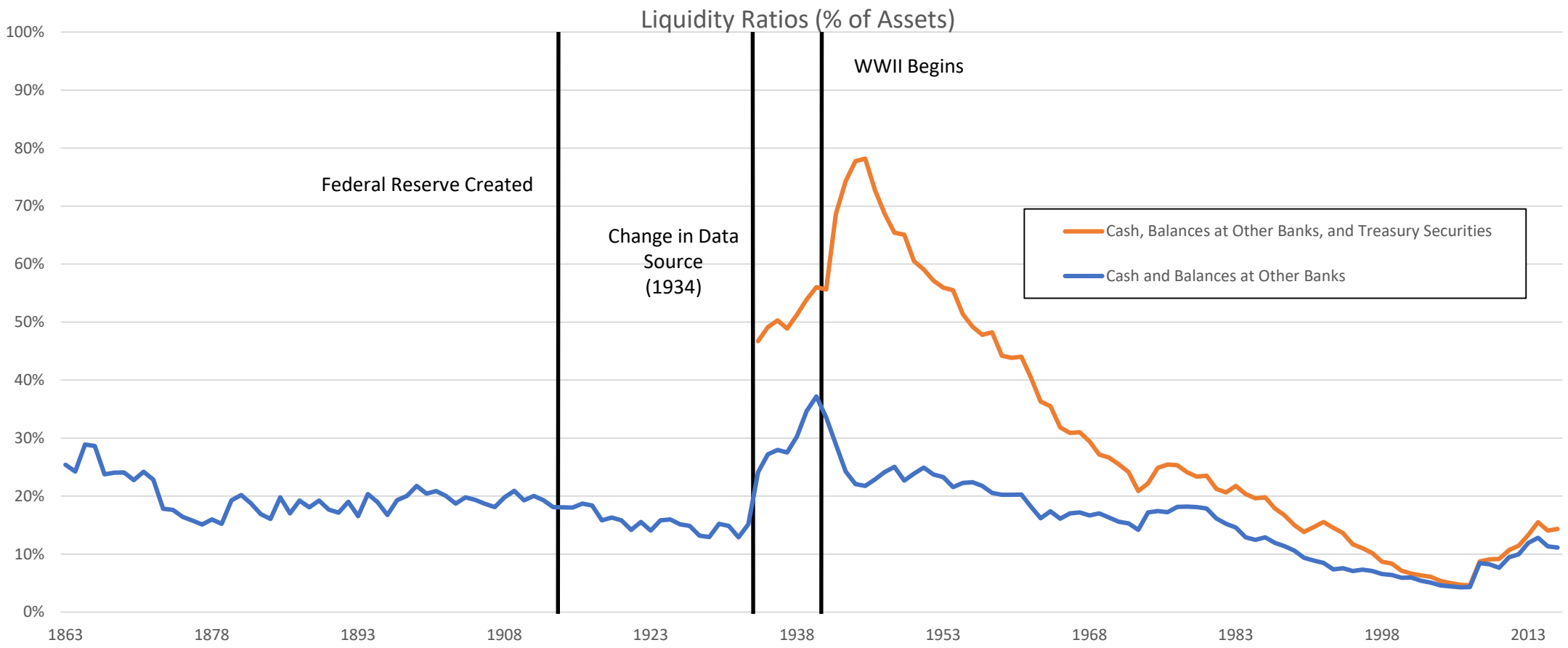
- Main safety and soundness regulation was a liquidity regulation (reserve requirement)
  - National Banks had to hold assets in the form of specie, Treasury notes, or reserves at other banks against 25% of their notes and deposits.
    - Precise requirement depended on whether a bank was a Central Reserve City bank, a Reserve City Bank, or a Country Bank
    - Some state banks had similar requirements.
  - If violated by a national bank, Comptroller of Currency could take away charter.

- Era characterized by multiple panics (1873, 1884, 1890, 1893, 1907)

- Experts from era (e.g., Sprague (2010)) blamed liquidity requirements for making panics worse. Said it created hoarding of liquidity.

- In practice, Comptroller seemed to ignore the rule during a panic

Reserves over Time



Source: 1863-1933 (Census Bureau); 1934-2017 (FDIC Historical Statistics on Banking)

History of Reserves Post Fed Founding

- Liquidity holdings of banks decline after founding of Fed (Carlson and Wheelock (2016))

- Fed stops thinking of reserve requirements as safety and soundness regulation, but instead to control credit conditions.

"The committee takes the position that it is no longer the primary function of legal reserve requirements to assure or preserve the liquidity of the individual member bank. The maintenance of liquidity is necessarily the responsibility of bank management and is achieved by the individual bank when an adequate proportion of its portfolio consists of assets that can be readily converted into cash. Since the establishment of the Federal Reserve System, the liquidity of an individual bank is more adequately safeguarded by the presence of the Federal Reserve banks, …." (Federal Reserve Committee on Bank Reserves (1931))

History of Reserves Post Fed Founding (cont.)

- In 1950s and until 1970s, bank reserves viewed as monetary policy tool
  - Chairman Martin, excess free reserves a signal about monetary policy
- Subsequent drop in level
  - Requirements drop, banks find ways around
  - Note: no interest paid on reserves by law (until recently)
    - During high inflation 1970s, gave incentives to arbitrage
  - For monetary policy, Fed starts targeting overnight rate
- Goes up during 2008 and then more so after
- Viewed once again as a safety and soundness regulation, but via contribution to LCR and NSFR.

Question Studied

- Effect of liquidity regulations on
  - Investment decisions
  - Failures
  - Functioning of interbank market

- Use an experimental design with
  - Investment decisions and bank failures
  - Heterogeneous withdrawal shocks across banks
  - An interbank market that supplies liquidity to meet withdrawals

Literature

- Macro models that look at welfare effects of liquidity regulations
  - These papers gets at investment distortions and value of bank liquidity services
  - De Nicolo, Gamba, and Luccheta (2012), Van den Heuvel (2016), Covas and Driscoll (2014), Hartley (1993)
  - This literature pretty undeveloped.

- Liquidity regulations and individual bank runs
  - Use Diamond-Dybvig model – Diamond and Kashyap (2016) survey only lists a few papers

- Interbank lending
  - Models where interbank lending is a source of liquidity
    - Bhattacharya and Gale (1987) – banks hold too few reserves (pecuniary externality)
    - Gale and Yorulmazer (2013) – incomplete markets, several stages. Liquidity requirements reduce chance of a panic, but make panic worse if one happens. Get liquidity hoarding for precautionary reasons
    - Speculative motives (Diamond and Rajan (2011)), Counterparty Risk (Heider et al. (2015))
    - Allen, Carletti, and Gale (2009)
  - Empirical evidence on hoarding behavior
    - National Banking Era
    - Recent crisis – Berrospide (2013)

Why Use Experiments

- A different source of evidence
  - Can control environment

- Empirical evidence scarce
  - Don’t have many panics, plus some evidence from different money and banking regimes (e.g., National Banking era)

- Experiments
  - Small set of papers that use this tool for financial regulation questions
  - Most look at D-D runs
  - Market price triggers (e.g., CoCos), Davis, Korenok, and Prescott (2014), Davis and Prescott (2017)
  - Interbank markets – Davis (2017)

Experimental Design

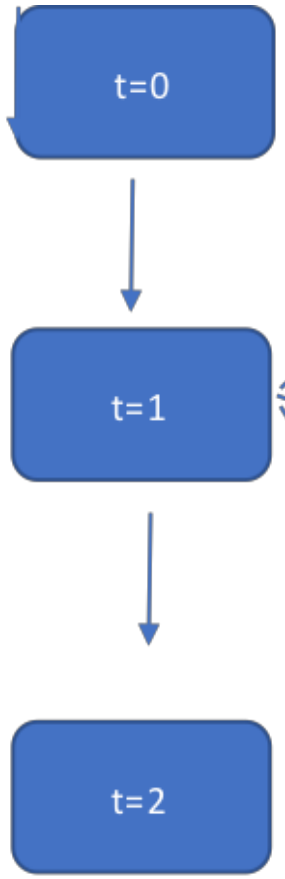
- **3 or 4 stage game**
  - Elements of Allen, Carletti, and Gale (2009), Gale and Yorulmazer (2015)

- **Stage 0**
  - 8 banks, each endowed with $12 in deposits
  - Portfolio decision
    - **Assets** – cost $1, yield $2 in final period
    - **Cash** – return of 0, but can be used to meet withdrawals and to purchase assets

- **Stage 1 (and 2)**
  - Liquidity shocks occur (withdrawals from banks)
  - Banks that need cash may sell assets to banks with excess cash (interbank market)
  - If can't meet cash withdrawal, bank fails and lose $4.00

- **Final stage**
  - Assets mature, deposits repaid, earnings determined

Simple Shock Environment



Eight banks – each has \$12 in deposits. Each invests (12-c_{i1}) in assets at P_0=\$1, and c_{i1} in cash

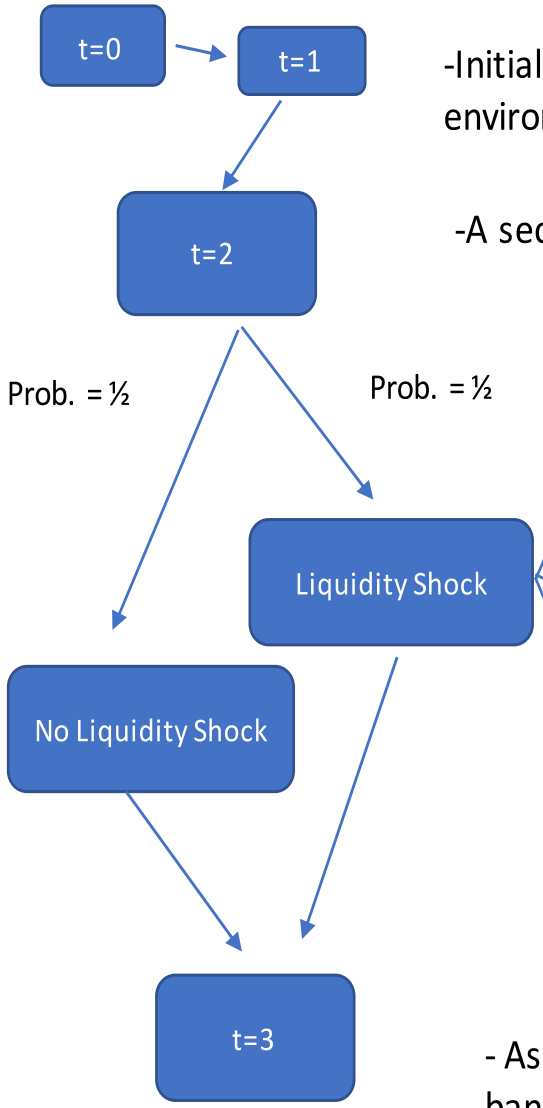
-Shocks: Four randomly selected banks are hit with an \$8.00 liquidity shock, creating a liquidity demand $d_1 = \sum_{i=1}^{4}(8 - c_{i1})$

-Banks not impacted by the shock make cash supply decisions $y_j(c_{j1}, d_1)$ to determine the cash supply $Y_1 = \sum_{j=1}^{4} y_j(c_{j1}, d_1)$

- Trading: Collective supply determines $P_1 \in \{\$1, \$2\}$, and trades occur until cash need is satisfied. Any bank that cannot meet its liquidity shock goes bankrupt and receives a payoff of -\$4.00.

Assets mature, deposits repaid and earnings determined.

Compound Shock Environment.



-Initial Investment, Shocks, and Trading, as in Simple Shock environment (See Figure 1).

-A second stage shock occurs with probability ½

-Shocks: Two of the four banks not hit with a stage-1 shock are randomly selected and hit with an $8.00 liquidity shock creating a liquidity demand $d_2 = \sum_{i=1}^{2}(8 - c_{i2})$

-Banks not Impacted by the shock make cash supply decisions $z_j(d_2, c_{j2})$ to determine the cash supply $Z_1 = \sum_{j=1}^{2} z_j(d_2, c_{j2})$

-Trading: Collective supply determines $P_2 \in \{\$1, \$2\}$, and trades occur until cash need is satisfied. Any bank that cannot meet its liquidity shock goes bankrupt and receives a payoff of -$4.00.

- Assets mature, deposits repaid and earnings for solvent banks determined.

Two Regulatory Regimes

- **Unregulated**
  - Banks choose how much cash to hold

- **Liquidity requirements**
  - Banks must hold at least $4 in cash when making investment decision
  - These reserves can be used for withdrawals if bank hit by shock
  - They **cannot** be used to alleviate other banks' liquidity needs

Four Cases

- Simple shock, baseline (SB)
- Simple shock, liquidity requirement (SL)
- Composite shock, baseline (CB)
- Composite shock, liquidity requirement (CL)

Interbank Trading

- In practice
  - Many interbank trades are bilateral
  - Complicated to implement as an experiment

- One alternative commonly used in experiments
  - Double auction (bids and asks made)
  - In these experiments, generates lots of price volatility (Davis et al. (2019))

- Our choice
  - After each shock, aggregate cash needs displayed
  - Banks with excess reserves decide how much to supply
  - Price
    - If Supply of cash $\leq$ Demand for cash, all reserves supplied trade. P_1=\$1
    - If Supply of cash > Demand for cash, the demand is satisfied. P_1=\$2

Pricing

- Prices are 1 or 2

- Can get situations that not enough cash to meet demand. In this case allocate like in the following example:
  - Example, Bank A needs 2 cash, Bank B needs 3 cash, Bank C needs 4 cash. Other banks only supply 7 units of cash.
    - P = 1 because $7 < 9$.
    - Allocate 2 to Bank A, Bank B, and Bank C. The 7^{th} unit allocated randomly to B or C.

Payoffs

- Payoffs
  - Failure (can’t meet withdrawals in either period)
    - Period earnings = -$4.00
  - If don’t fail
    - Period earnings = 2*assets + cash - deposits
    - assets and cash are what you hold in last stage
  - If just held cash for the entire game get $0.00.
  - If only hold assets and get no liquidity shocks, get $12.00.

Simple Shock (SB, SL)

- Simple Shock Baseline (SB)
  - Initial investment: (8 assets, $4 cash)
  - Stage 1 trading, each unshocked bank supplies $4 in reserves, $P_1 = \$1$
  - 64 assets mature
  - Expected earnings: (1/2)($4)+(1/2)($12) = $8

- Simple Shock with LCR (SL)
  - Initial investment: (6 assets, $6 cash)
  - Stage 1 trading, each unshocked bank supplies $2 in reserves, $P_1 = \$1$
  - 48 assets mature
  - Expected earnings: (1/2)($4)+(1/2)($8) = $6

- Both allocations are unique symmetric subgame perfect Nash equilibrium (**SPNE**)
- Will use **SPNE** as a benchmark allocation

Compound Shock (CB) – 2 SPNE

- “No Exposure” Equilibrium
  - Initial investment (6 assets, $6 cash)
  - 48 assets mature
  - Expected earnings: (1/2)($4)+(1/4)($8)+(1/8)($12)+(1/8)($4) = $6

- “Exposure” Equilibrium
  - Initial investment: (8 assets, $4 cash)
  - 48 assets mature
  - Expected earnings: (1/2)($4)+(1/4)($12)+(1/8)($12)+(1/8)(-$4) = $6

  - “Exposure” equilibrium exists unless B>$20.

Compound Shock with LCR (CL) – 2 SPNE

- “No Exposure” Equilibrium
  - Initial investment (5 assets, $7 cash)
  - 40 assets mature
  - Expected earnings: (1/2)($4)+(1/4)($6)+(1/8)($8)+(1/8)($4) = $5

- “Exposure” Equilibrium
  - Initial investment: (6 assets, $6 cash)
  - 48 assets mature
  - Expected earnings: (1/2)($4)+(1/4)($8)+(1/8)($8)+(1/8)(-$4) = $4.50

- “Exposure” equilibrium exists unless B>$8.

SPNE Benchmarks

Treatment	Period 0 Reserves	Expected Payoff	Total Initial Investment
SB	$4	$8.00	64
CB – *ne*	$6	$6.00	48
CB – *e*	$4	$6.00	64
SL	$6	$6.00	48
CL – *ne*	$7	$5.00	40
CL– *e*	$6	$4.50	48

Note: *CL* 'exposure' equilibria is less attractive than *CB* counterpart

Use these as benchmarks to compare with observed behavior.

Experiment Procedures

- 12 sessions. Each session consisted of two 8-bank markets.

- All sessions start with instructions for the *SB* regime.
  - 2 practice periods followed by 3 paid periods (also practice)
- Session paused. Instructions for treatment read {*SB, SL, CB, or CL*}
  - 2 practice periods followed by 18 paid periods

- In total 24 independent markets, 6 in each treatment.

- Results based on 18 treatment periods in each market, follow practice periods.

- Participants play in lab dollars. Converted to U.S. dollars at a rate of 10 to 2.

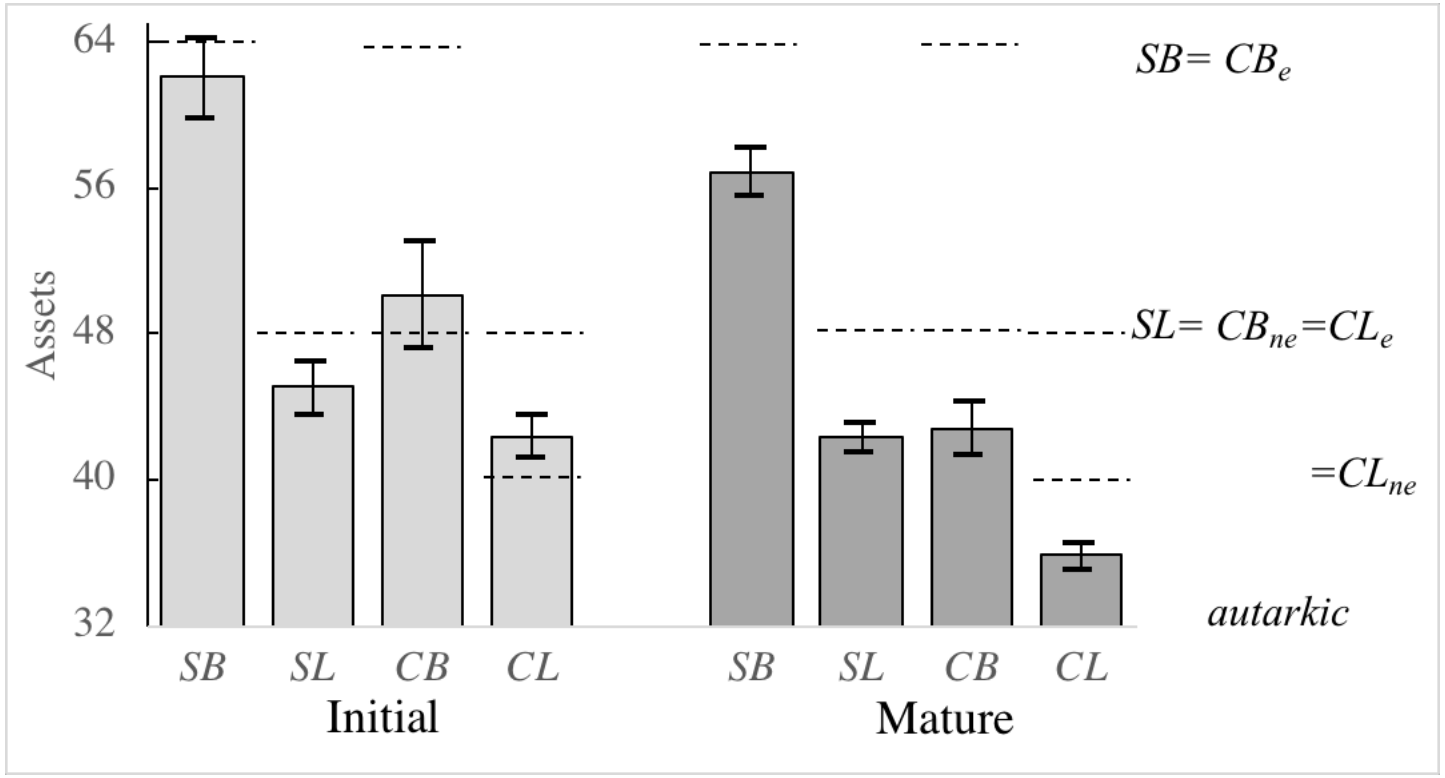
- 196 Participants. Math, engineering, economics undergrads at VCU.

- Earnings ranged from $15.60 to $45.00 and averaged $29.20 for 90 minutes sessions.

Focus of Analysis

- Investment efficiency
- Stability (bankruptcy rates)
- Liquidity management/hoarding

Investment Results

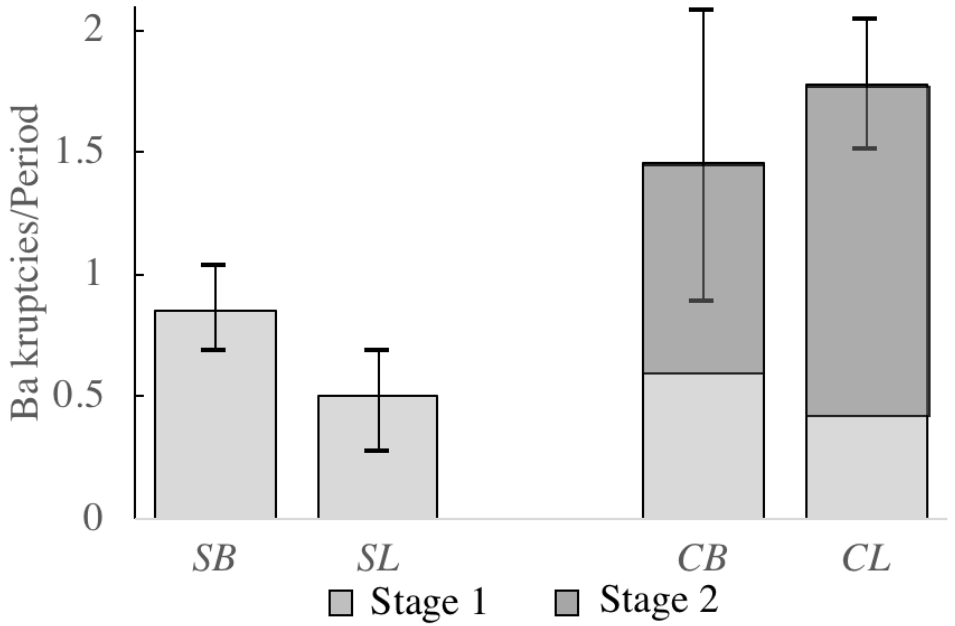


Investment Results

- Investment exceeds autarkic levels (32)
  - Players relying on interbank market to meet withdrawals
- Relative to SPNE equilibria
  - Simple shock – less investment on average
  - Compound shock – modestly higher investment on average
- Liquidity requirements
  - Reduces investment (as it should)

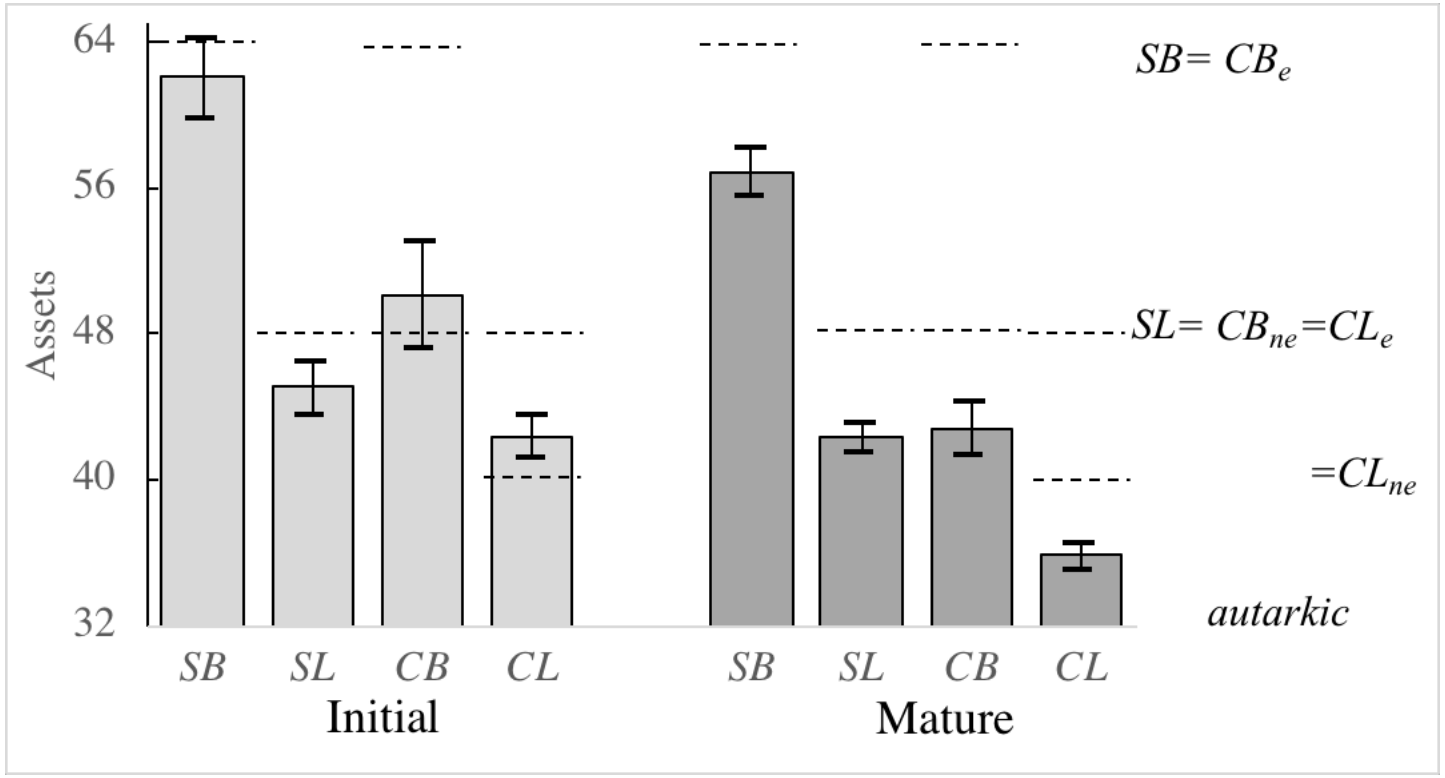
Failure Results

- **Overall:** Bankruptcies occur
- **Simple Shock**: Bankruptcies less frequent with liquidity regulations.
- **Compound Shock:** Liquidity requirements reduce first-stage bankruptcies, but increase second-stage bankruptcies.



Note: Stage 2 bankruptcy rates are contingent on stage 2 shock occurring.

Successful Investments



Some Questions

- In the simple shock environment, why so many bankruptcies when average investment below SPNE level?

- Why do liquidity regulations reduce bankruptcies?

- Why are there more 2nd-stage bankruptcies in the CL environment than the CB environment?

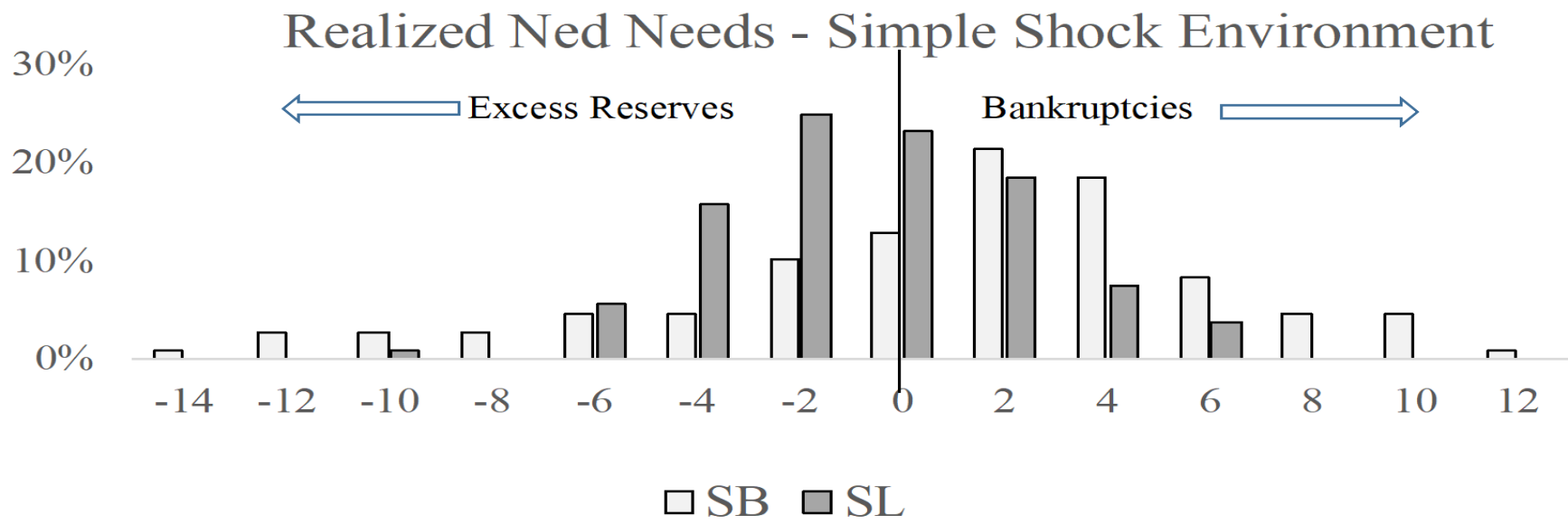
Baseline Simple Shock Environment

- Mean investment below the SPNE, which had no bankruptcies.
- But bankruptcies average 0.85 per period.

- Reason: mean levels hide significant variation in individual decisions and in periods
  - Players even change strategies over time

- Only need one more unit of investment greater than the maximum sustainable level to get a bankruptcy.

Variation in Net Needs for Liquidity



At least one bank will be bankrupt if net need is positive.

Some banks with cash don't release it in order to try and get P=1. Strategic motivation to hoard liquidity.

More variation in SB. Liquidity regs restrict variation in investment levels.

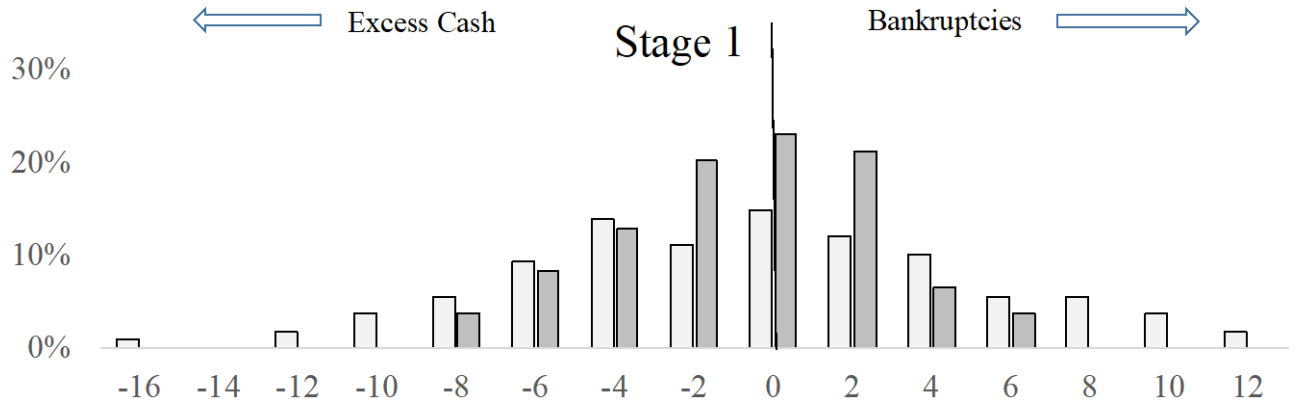
Reasons for Insufficient Reserves

1. Overinvestment
2. Banks with excess cash withhold some to try and get P=1 (a form of hoarding)
3. See both reasons in some cases

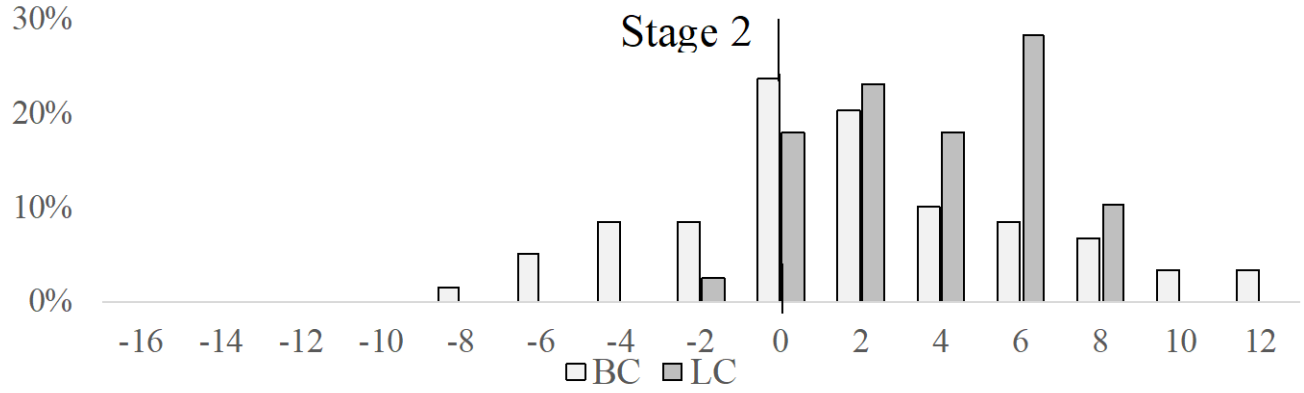
	Realized	Initial	Withholding Induced
Simple Shock Environment			
SB	51.85%	38.89%	28.70%
SL	29.63%***	14.8%***	21.20%
Compound Shock Environment 1st Stage			
CB	38.90%	55.60%	13.89%
CL	31.50%	65.70%	5.50%*
Compound Shock Environment 2nd Stage			
CB	53.00%	40.15%	25.00%
CL	79.80%**	75.12%***	25.90%

Net Needs for Compound Shock

1) First Stage: LC banks again generate fewer first stage bankruptcies than BC banks.



2) In the second stage LC have too few available reserves. (Note: partly because have to hold $4.)



Failure Results

- Liquidity requirements, Compound Shock (LC)
  - Reduce 1st stage bankruptcies
    - Reason is that they are holding more cash and banks subject to the withdrawal shock need less cash.
  - But increase 2nd stage bankruptcies
    - Large cash demand by two banks. Liquidity requirements are tying up a lot of cash. This is one type of “liquidity hoarding”. Just not holding enough cash for period 2.

Hoarding in Compound Shock Environment

- First stage
  - In CL, banks are withholding cash less than in CB
  - Less 1st stage bankruptcies
  - Less of this type of hoarding

- Second stage
  - Have large cash demand by two banks
  - Liquidity requirements are tying up a lot of cash
  - Banking system needs to have saved a lot of cash because of this and it doesn't
  - Different type of hoarding (and closer to historical concept)
    - Friedman's "taxi stand"

Summary

- Looking at how liquidity regulation affect the interbank market

- Suggests costs to these regulations
  - Pulls liquidity out that could help in the interbank market
    - Some strategic behavior
  - Does help in initial period, but not second period
  - Significant cost in foregone investment on average

- Lots of variety in investment across periods and even by people over time
  - Coordination problem in investment
  - Frequent over investment

- Hoarding less important than aggregate investment for bankruptcies
  - Though Friedman taxi stand story a factor

Summary/Caveats

- Paper is exploratory
  - Very sparse environment
  - Lot of departures from observed institutions
    - Cash leaves system – like a currency withdrawal, not a transfer of reserve on a central bank balance sheet
    - No central bank
    - Trade is stylized
  - Very large liquidity shocks
- We view as a first step towards finding a useful experimental design for interbank market questions

Investment Results

Table 2 Initial Investments

(1) Treatment	(2) $\overline{inv_i}$	(3a) *msi*	(3b) $\overline{inv_i}$-*msi*	(4a) *ei-e*	(4b) $\overline{inv_i}$- *ei-e*	(5) *BS-LS*	(6) *BC-LC*
BS	62.08	64	-1.92*				
LS	45.06	48	-2.94***			17.02***	
BC	50.15	48	2.15	64	-13.85***		
LC	42.34	40	2.34***	48	-5.66***		7.81***

Key: $\overline{inv_i}$ denotes mean initial investment, *msi* denotes maximum sustainable investment, and *ei-e* denotes equilibrium investment in the exposure equilibrium (for the *BC* and *LC* treatments only). *, ** and *** denote rejections of the null that the listed difference equals zero, $p<0.10$, 0.05 and 0.01, respectively. In all treatments $\overline{inv_i}$ exceeds the autarkic level of 32 units at $p<0.01$.

Calculated from regression: $y_{it} = \beta_0 + \beta_L D_L + \beta_C D_C + \beta_{CL} D_C D_L + \varepsilon_i + u_{it}$

Failure Rates

Table 3 Bankruptcies (Average per Period)

(1) Treatment-Period	(2) 1st Stage Rate	(2) B - L	(3) 2nd Stage Rate	(3) B - L	(4) Total Rate	(4) B - L
			All Periods			
Simple Shock Environment						
BS	0.85		---		0.85	
LS	0.51	0.34***	---	---	0.51	0.34***
Compound Shock Environment, Second Stage Shock						
BC	0.62		0.86		1.47	
LC	0.41	0.21	1.38	-0.52**	1.77	-0.30

Note: Calculated from a regression model.

Variation in Individual Strategies

Table 4. Homogeneity and Stability of Individual Investment Decisions

Treatment	*BS*	*LS*	*BC*	*LC*
Symmetric SPNE Investment ('SNE')				
	8	6	6	5
Homogeneity of Individual Investment Decisions				
<SNE-3	11%	0%	0%	0%
<SNE-1	32%	33%	35%	0%
SNE	28%	29%	18%	20%
>SNE+1	20%	18%	25%	18%
>SNE+3	13%	0%	13%	0%
Change in Investment Decisions Across Periods				
No change	50%	57%	54%	54%
+2 or more	29%	25%	27%	26%
+4 or more	12%	6%	12%	5%
+6 or more	5%	0%	7%	0%

Experience Effects

Table 3 Bankruptcies (Average per Period)

(1) Treatment-Period	(2) 1st Stage Rate	(2) 1st Stage B - L	(3) 2nd Stage Rate	(3) 2nd Stage B - L	(4) Total Rate	(4) Total B - L
Periods 1-9						
Simple Shock Environment						
BS	0.67		---		0.67	
LS	0.41	0.26*	---	---	0.41	0.26*
Compound Shock Environment, Second Stage Shock						
BC	0.55		0.79		1.35	
LC	0.47	0.07	1.55	-0.76***	2.02	-0.67
Periods 10-18						
Simple Shock Environment						
BS	1.04†††				1.04†††	
LS	0.59†††	0.44***	---	---	0.59†††	0.44***
Compound Shock Environment, Second Stage Shock						
BC	0.72		0.93		1.63	
LC	0.36	0.35***	1.23	-0.30	1.59†††	0.04

Key: *, **, *** Reject H_o that bankruptcy rate in the Baseline regime does not differ significantly from the rate for the comparable Liquidity Regulations regime, $p<.10$, $p<.05$ and $p<.01$, respectively. . In the bottom panel of the table †,†† and††† denote rejections of the null that mean initial investment does not change across session halves, $p<0.10$, 0.05 and 0.01, respectively