Finance and AI

Banking: lending capacity and runs

Fatih Kansoy

Worcester College, University of Oxford

Day 2

Day 2 outline

1) How much can banks lend?
2) Why can a bank die in a day?
3) What kills a run?

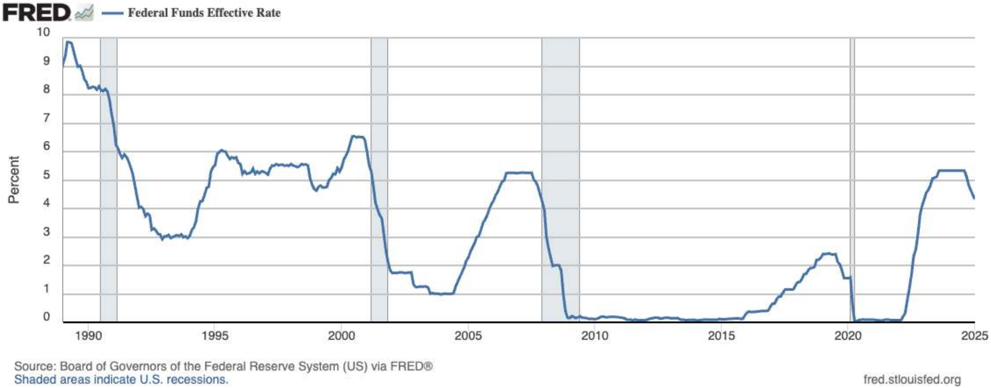
Power of Bad News

YouTube Video (Click to Open)

Power of Bad News

The Metro Bank hoax shows the immense power of fake news on WhatsApp

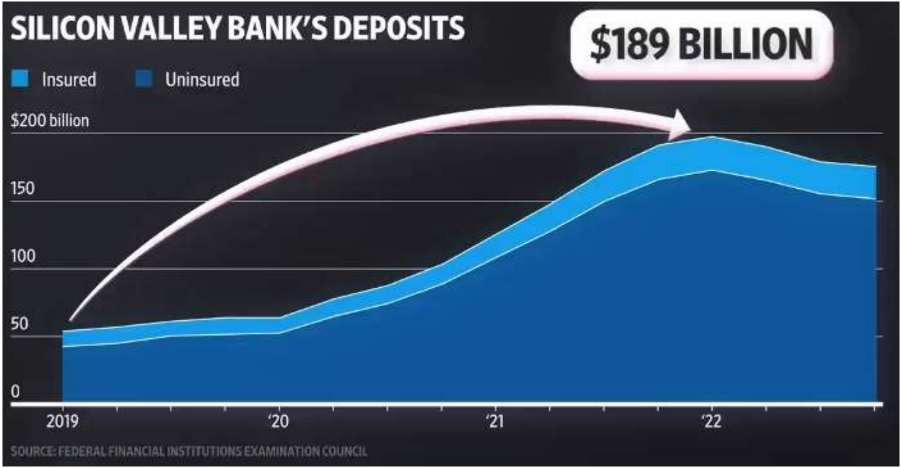
The U.S. Federal Funds Rate since 1990



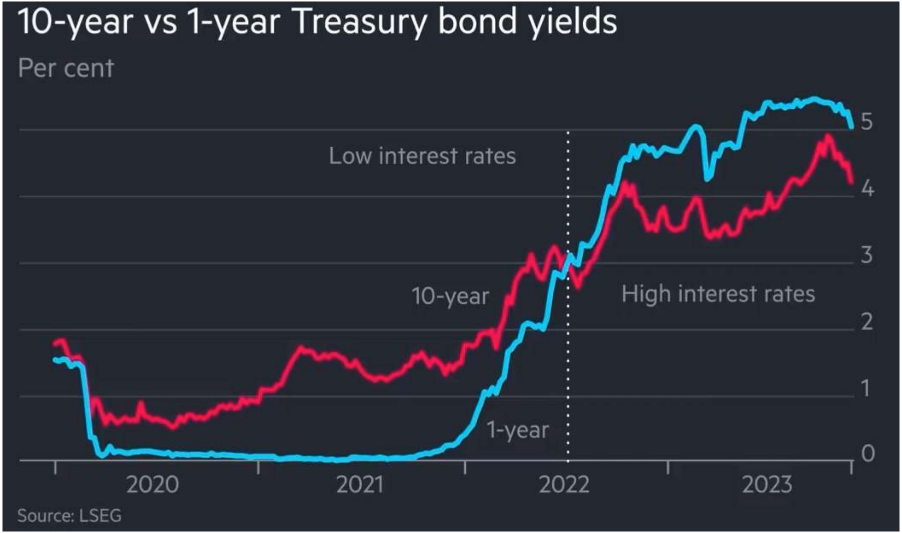
Interactive Chart (Click to Open)

Hub of Tech Companies

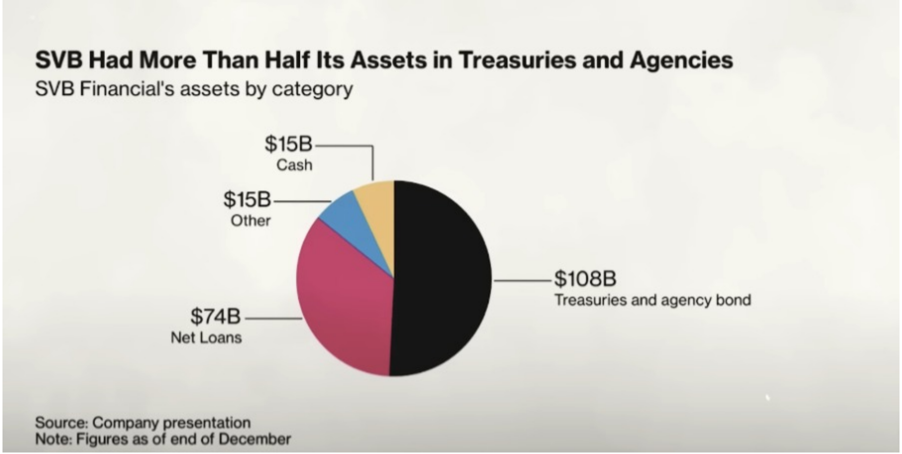
The Good Old Days



The Good Old Days

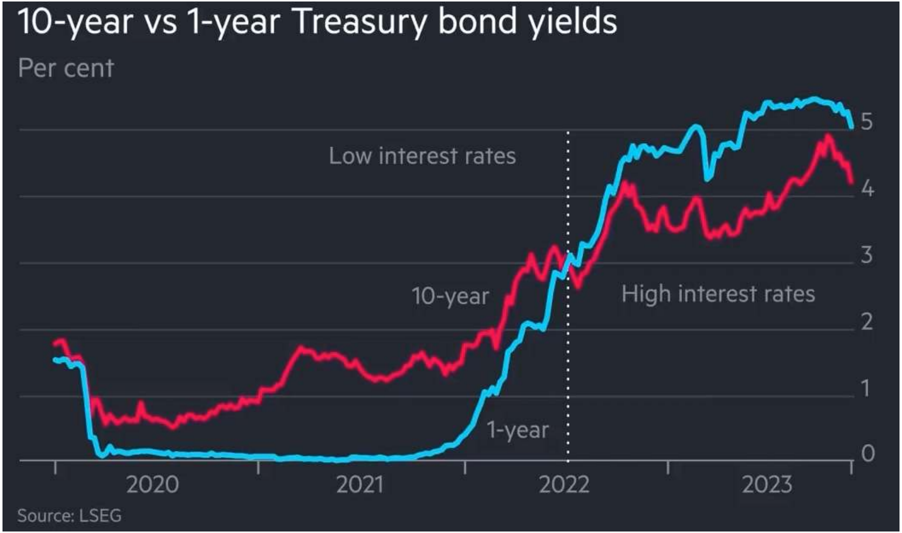


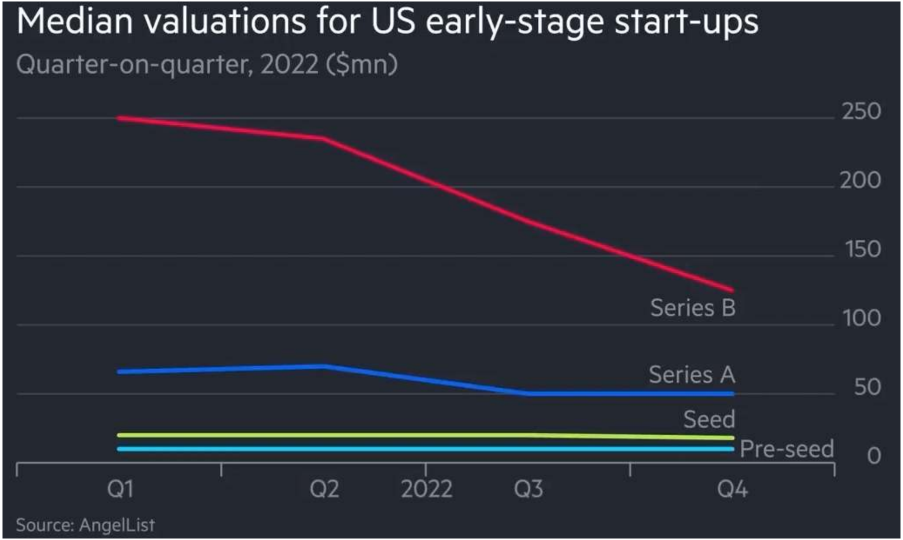
The Good Old Days



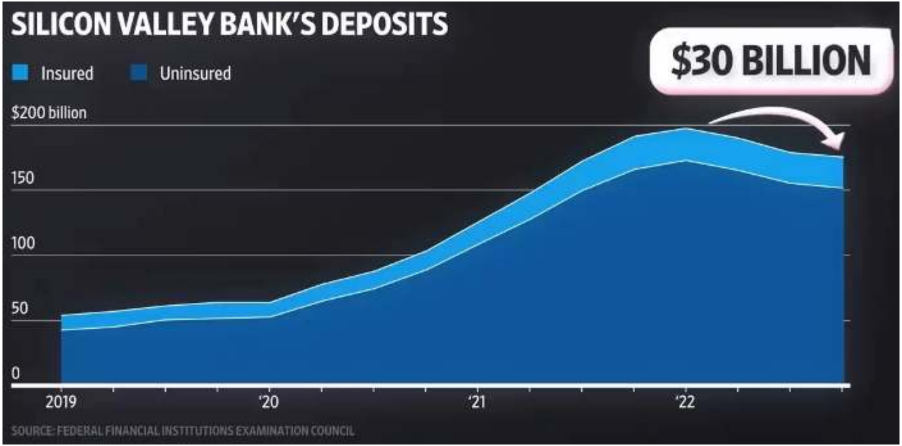
Fed Sent shockwaves

The Good Old Days




Median valuations for US early-stage start-ups
Quarter-on-quarter, 2022 ($mn)
250
200
150
100
50
0
Series B
Series A
Seed
Pre-seed
Q1
Q2
2022
Q3
Q4
Source: AngelList

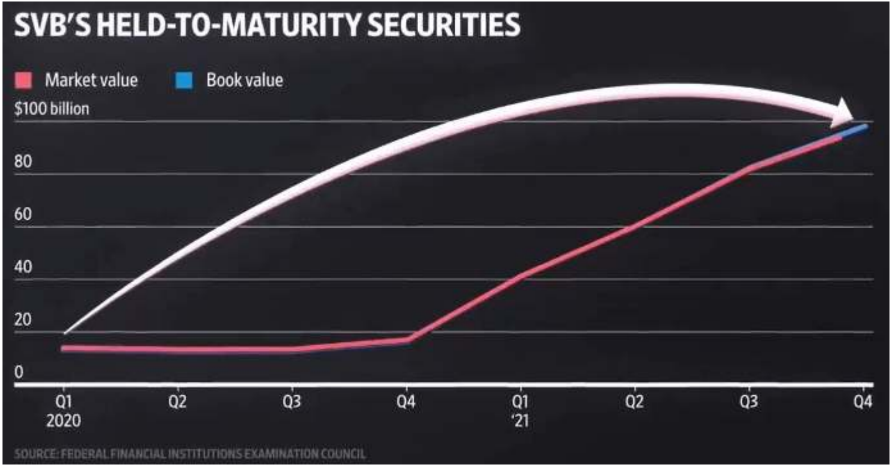
A little more withdraw



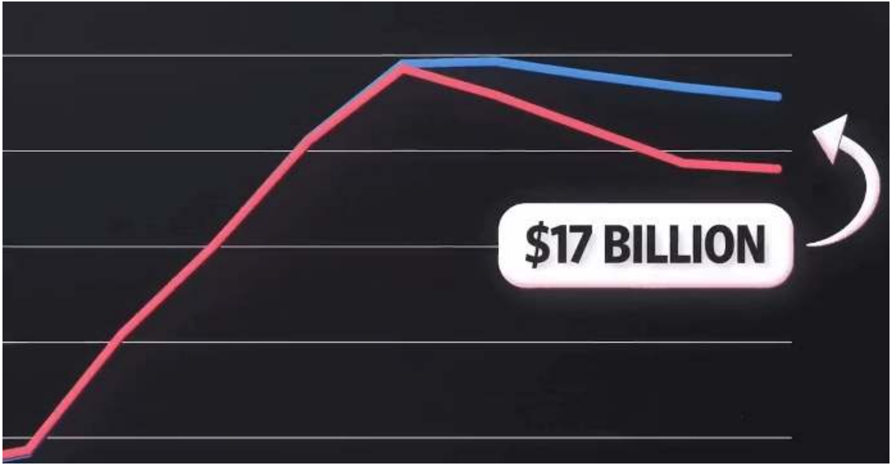
A long-term change

Interactive Chart (Click to Open)

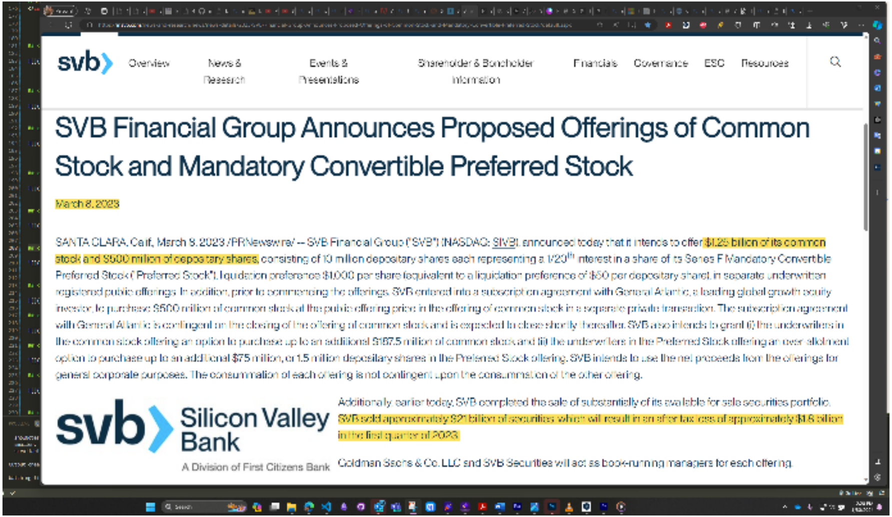
A long-term change



A long-term change



Spark that will set the whole place on fire



Overview | News & Research | Events & Presentations | Shareholder & Bondholder Information | Financials | Governance | ESG | Resources

SVB Financial Group Announces Proposed Offerings of Common Stock and Mandatory Convertible Preferred Stock

March 8, 2023

SANTA CLARA, Calif., March 8, 2023 /PRNewswire/ -- SVB Financial Group ("SVB") (NASDAQ: SIVB), announced today that it intends to offer $1.25 billion of its common stock and $500 million of depositary shares, consisting of 10 million depositary shares each representing a 1/20th interest in a share of its Series F Mandatory Convertible Preferred Stock ("Preferred Stock"), liquidation preference $1,000 per share (equivalent to a liquidation preference of $50 per depositary share), in separate underwritten registered public offerings. In addition, prior to commencing the offerings, SVB entered into a subscription agreement with General Atlantic, a leading global growth equity investor, to purchase $500 million of common stock at the public offering price in the offering of common stock in a separate private transaction. The subscription agreement with General Atlantic is contingent on the closing of the offering of common stock and is expected to close shortly thereafter. SVB also intends to grant (i) the underwriters in the common stock offering an option to purchase up to an additional $187.5 million of common stock and (ii) the underwriters in the Preferred Stock offering an over-allotment option to purchase up to an additional $75 million, or 1.5 million depositary shares in the Preferred Stock offering. SVB intends to use the net proceeds from the offerings for general corporate purposes. The consummation of each offering is not contingent upon the consummation of the other offering.

Silicon Valley Bank

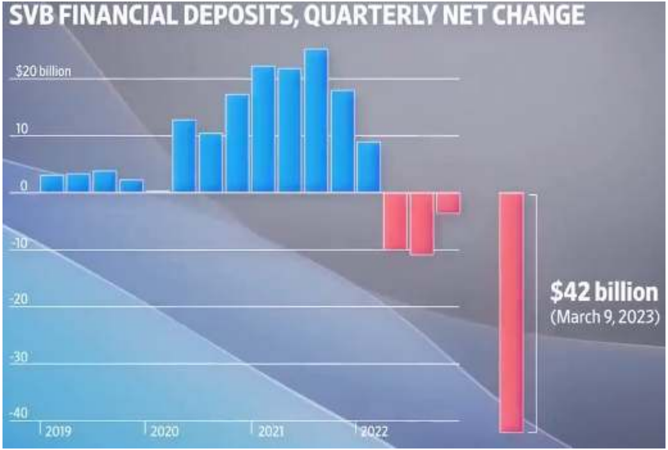
A Division of First Citizens Bank

Additionally, earlier today, SVB completed the sale of substantially of its available for sale securities portfolio. SVB sold approximately $21 billion of securities which will result in an after tax loss of approximately $1.8 billion in the first quarter of 2023.

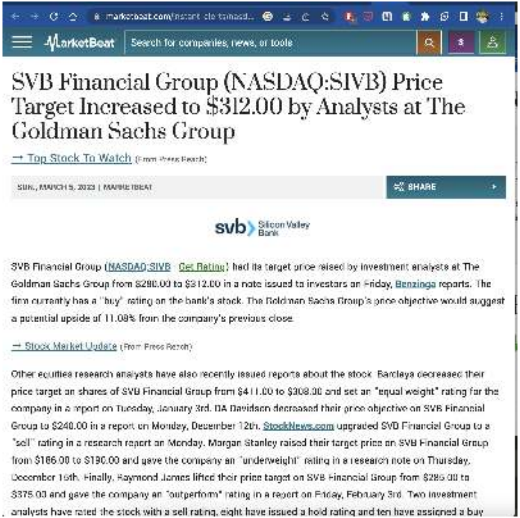
Goldman Sachs & Co. LLC and SVB Securities will act as book-running managers for each offering.

Beginning of the end

The End


SVB FINANCIAL DEPOSITS, QUARTERLY NET CHANGE
$20 billion
10
0
-10
-20
-30
-40
2019
2020
2021
2022
$42 billion
(March 9, 2023)

Moral Hazard



MarketBeat

SVB Financial Group (NASDAQ:SIVB) Price Target Increased to $312.00 by Analysts at The Goldman Sachs Group

→ Top Stock To Watch (From Press Reach)

SUN., MARCH 5, 2023 | MARKETBEAT

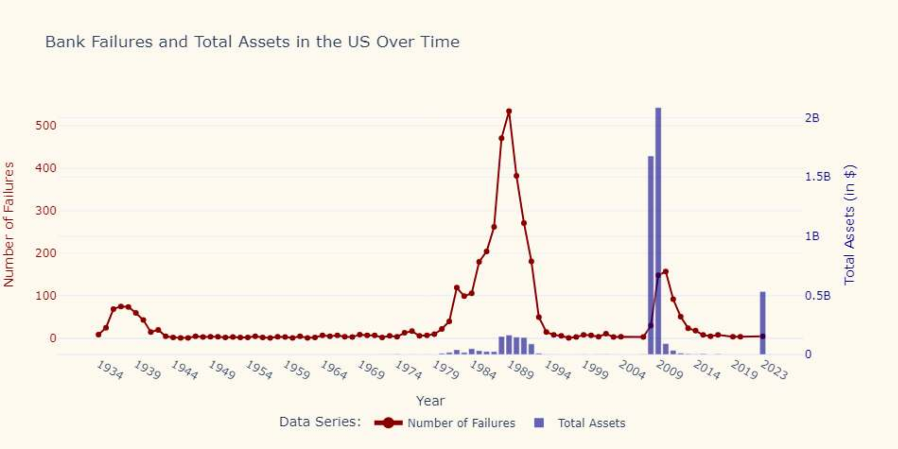
SHARE

SVB Financial Group (NASDAQ:SIVB - Get Rating) had its target price raised by investment analysts at The Goldman Sachs Group from $280.00 to $312.00 in a note issued to investors on Friday, Benzinga reports. The firm currently has a "buy" rating on the bank's stock. The Goldman Sachs Group's price objective would suggest a potential upside of 11.08% from the company's previous close.

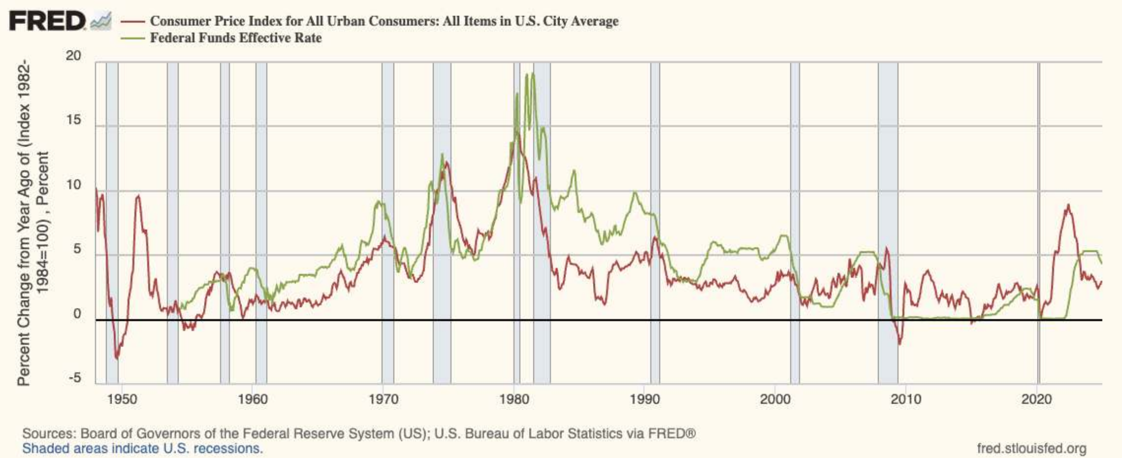
→ Stock Market Update (From Press Reach)

Other equities research analysts have also recently issued reports about the stock. Barclays decreased their price target on shares of SVB Financial Group from $411.00 to $308.00 and set an "equal weight" rating for the company in a report on Tuesday, January 3rd. DA Davidson decreased their price objective on SVB Financial Group to $240.00 in a report on Monday, December 12th. StockNews.com upgraded SVB Financial Group to a "sell" rating in a research report on Monday. Morgan Stanley raised their target price on SVB Financial Group from $186.00 to $190.00 and gave the company an "underweight" rating in a research note on Thursday, December 15th. Finally, Raymond James lifted their price target on SVB Financial Group from $285.00 to $375.00 and gave the company an "outperform" rating in a report on Friday, February 3rd. Two investment analysts have rated the stock with a sell rating, eight have issued a hold rating and ten have assigned a buy

Lessons from [Financial] History?



Lesson from Financial History?

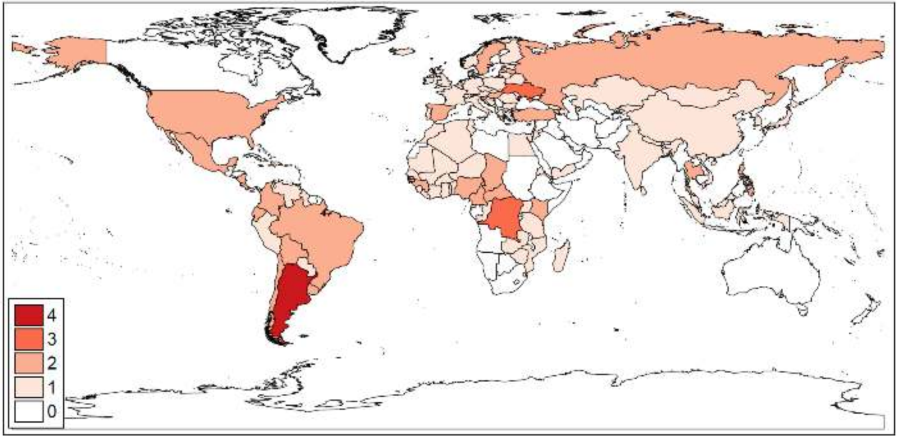


Interactive Chart (Click to Open)

Regulation $\neq$ Bureaucracy

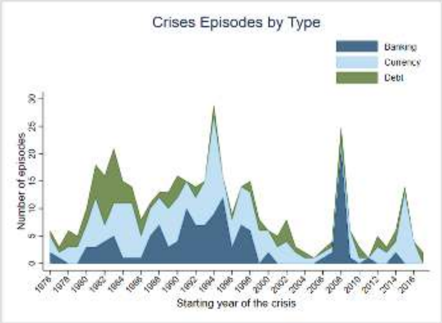
YouTube Video (Click to Open)

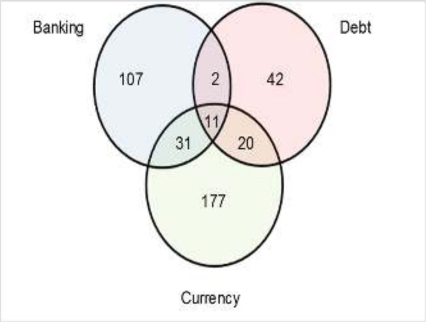
Not Just US and Not Just in 2023



Laeven, M.L. and Valencia, M.F., 2018. Systemic banking crises revisited. IMF.

Not Just the US and Not Just in 2023





Laeven, M.L. and Valencia, M.F., 2018. Systemic banking crises revisited. IMF.

Models that explain banking


FINANCIAL TIMES

Silicon Valley Bank Added

Top Fed official blasts SVB collapse as 'textbook case of mismanagement'

Michael Barr said US central bank's board had been briefed on troubles at California lender in mid-February

In testimony released ahead of an expected grilling on SVB's failure by US lawmakers on Tuesday, Michael Barr, the Fed's vice-chair for supervision, criticised the bank's 'concentrated business model' © Bloomberg

James Politi and Lauren Fedor in Washington MARCH 27 2023

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- **Diamond and Dybvig** (*JPE*, 1983): runs driven by expectations. **Our main model today.**
- **Gertler and Karadi** (*JME*, 2011): agency costs limit how much a bank can borrow.
- **Gertler and Kiyotaki** (*AER*, 2015): the two forces together, balance sheets and runs.
- Milgrom and Roberts (1992): moral hazard inside the bank.

Two questions, one method

- **Question 1: how much can a bank lend?**
  - Model 1: two periods; depositors must trust the banker (Gertler–Karadi 2011; Gertler–Kiyotaki 2015).
- **Question 2: why can a solvent bank die in two days?**
  - Model 2: Diamond–Dybvig (1983). Then three policies that kill runs.
- Method, both times: actors → objectives and budgets → choices → **equilibrium**.
- Assumed known: a balance sheet ($A = D + N$) and leverage. Everything else is built here, step by step.
- R_A = gross return on assets; R_D = gross return on deposits. The bottom-right buttons open full derivations; every appendix page links back.

Part I

How much can banks lend?

What disciplines the size of a bank's balance sheet?

A two-period economy with households, firms, and bankers whose promises must be credible. Net worth turns out to be the licence to intermediate.

The smallest economy that can hold a bank

- Two periods $\{1, 2\}$; one good.
- A **representative household** with endowment y in period 1; all members consume c_1 and c_2.
- Each household contains a **banker**, who runs a bank serving *other* households and brings its profit π home in period 2.
- **Firms** operate the production technology.
- A parable on purpose: small enough that every mechanism stays visible.

Two-period model after Gertler–Karadi (2011) and Gertler–Kiyotaki (2015); numerical calculations shown.

The household weighs today against tomorrow

- Choose c_1, c_2 and deposits D to maximise

$$U(c_1, c_2) \;=\; \sqrt{c_1} \;+\; \beta\,\sqrt{c_2}.$$

  - $\sqrt{c}$: diminishing marginal utility; $\beta \in (0,1)$: patience.
- Period 1: $c_1 + D = y$. Period 2: $c_2 = R_D D + \pi$.
  - π is the banker's profit, remitted home; its formula arrives on the banker's slide.
- The household takes R_D and π as given; the market determines them.

Appendix T1 Appendix T2

The Euler equation prices patience

- Substitute both budgets into U, set the derivative to zero (steps: A1):

$$\frac{1}{\sqrt{c_1}} = \beta R_D \frac{1}{\sqrt{c_2}} \qquad \Longleftrightarrow \qquad c_2 = (\beta R_D)^2 \, c_1 .$$

- Give up one unit today, receive R_D tomorrow: at the optimum the swap leaves utility unchanged.
- A higher R_D tilts the plan toward tomorrow (why the income effect loses: A2).

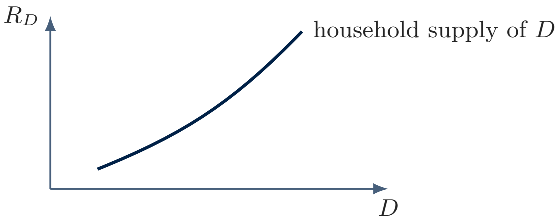
Appendix A1 Appendix A2

Deposit supply rises with the deposit rate

- Two budgets plus the Euler equation, three unknowns. Solving (A3):

$$c_1 = \frac{y + \pi/R_D}{1 + \beta^2 R_D}, \qquad D = y - c_1, \qquad c_2 = R_D D + \pi.$$

- Higher $R_D \Rightarrow$ lower $c_1 \Rightarrow$ higher D: deposit supply slopes upward – derived, not assumed.



Appendix A3

Firms turn goods today into more goods tomorrow

- Constant returns to scale: 1 unit invested in period 1 becomes $R_A > 1$ units in period 2.
- Firms are perfectly competitive, so they earn zero profit: the whole R_A per unit goes to the lender.
- Households cannot lend to firms directly: lending needs screening and monitoring. Banks can; individual savers cannot.
- That inability is why this economy needs a bank.

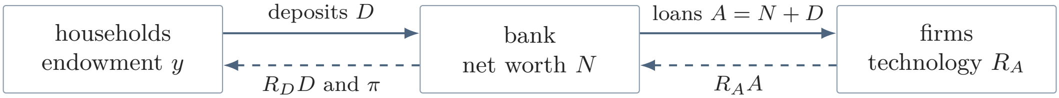
The banker adds net worth and runs a balance sheet

- Own funds N in period 1: the bank's **net worth**.
- Balance sheet: lend $A = N + D$.
- Profit, home in period 2:

$$\pi \;=\; R_A A - R_D D \;=\; (N + D)\, R_A - R_D\, D.$$

- If $R_A \geq R_D$, every deposit adds profit: the banker takes all the deposits households will give.

Net worth travels with every loan the bank makes



- Solid arrows: period 1. Dashed arrows: period 2. The bank stands between savers and firms because only it can lend.

Equilibrium means three statements hold at once

- **Equilibrium**: no actor can do better by changing their own choice, and all quantities add up. Here:

  1. households optimise, given (R_D, π);
  2. the banker optimises, given (R_D, R_A);
  3. markets clear: deposits supplied = deposits taken, and $A = N + D$.

Benchmark with honest bankers: $R_D = R_A$, first best

- Suppose bankers always repay. Then equilibrium forces $R_D = R_A$:
  - $R_D > R_A$: every deposit loses money – banks take none;
  - $R_D < R_A$: every deposit is pure profit – demand is unlimited.
- At $R_D = R_A$: profit is $\pi = NR_A$, and savers earn the full return on capital.
- The allocation is **first-best**: what a planner with no frictions would choose (A4).
- So far the bank is a perfect pipe. Now we let it leak.

Appendix A4

The banker can run off with a fraction λ

- **Moral hazard**: a hidden action taken after the money changes hands.
- In period 2 the banker can default and divert $\lambda\, R_A(N+D)$; depositors are left with the remaining $(1-\lambda)\, R_A(N+D)$.
- $\lambda \in (0,1)$: weak enforcement, opaque assets. The thin-equity failures of 2008 (Lehman) are the reminder.
- Depositors anticipate this, and lend only on terms that keep honesty worthwhile.

Depositors fund the bank only while honesty pays

- The **incentive constraint**:

$$\underbrace{(N + D)\, R_A - R_D\, D}_{\text{profit if honest}} \;\geq\; \underbrace{\lambda\, R_A\, (N + D)}_{\text{take if absconding}} \tag{IC}$$

- N is the crux. The banker's own money earns R_A on the honest side but only λR_A on the absconding side, so capital lifts the honest side faster. **Wealth makes a banker cheaper to trust.**

- (IC) is either **slack** (room to spare – as if no friction) or **binding** (equality – deposits stop exactly there). Which one depends on N.

- Default equilibria can be ignored without loss (A5).

Appendix A5

Nobody polices the banker. Depositors simply lend less

- There is no regulator, no court and no auditor in (IC). Depositors cannot watch what the banker does in period 2, and no contract can remove the option to abscond.
- What they can choose is *how much* to hand over. They stop at the last pound the banker will still choose to repay.
- So the limit is **self-enforcing**: priced in before the money moves, not punished afterwards.
- This is also what repairs the benchmark. There, deposit demand was unlimited. Now a bigger balance sheet is a bigger temptation, so the bank has a finite size.

Case 1: high net worth keeps the first best

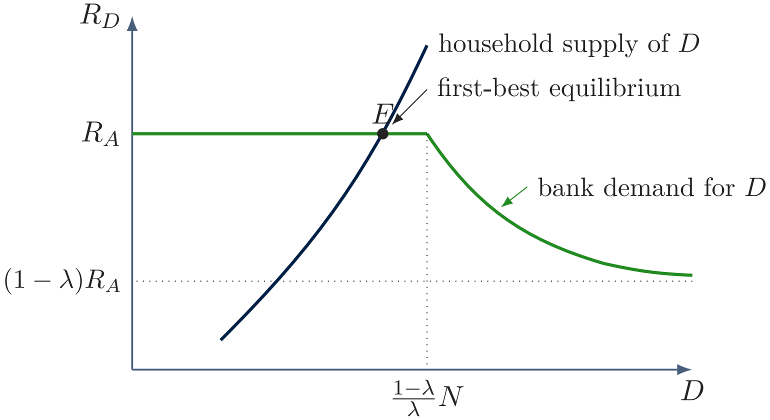
- Try the benchmark outcome $R_D = R_A$. Substituting into (IC) and rearranging (Appendix A6):

$$D \leq \frac{1-\lambda}{\lambda} N.$$

- Read it both ways:
  - deposits can be at most a multiple of net worth;
  - equivalently, net worth must be a large enough share of the balance sheet.
- **Skin in the game**: with enough of the banker's own wealth at stake, absconding burns more than it steals.
- With $\lambda = 0.15$: $D \leq 5.67\,N$. If households wish to save less than that, the friction never bites: $R_D = R_A$ and the first best survives.

Appendix A6

With high net worth, supply meets demand at the first best



- Supply crosses demand on the flat part: $R_D = R_A$, the constraint slack.

Reading the high-net-worth diagram

- **Axes:** deposits D on the horizontal axis; the promised deposit return R_D on the vertical axis.
- **Household supply:** the upward curve. Savers offer more deposits only if the return rises.
- **Bank demand:** flat at R_A up to $\frac{1-\lambda}{\lambda}N$, then bends down. On the flat part the bank can match the asset return; beyond the kink the credible promise falls as deposits rise relative to equity.
- **The kink** $\frac{1-\lambda}{\lambda}N$: the largest deposit book consistent with a slack incentive constraint. High N pushes this point far to the right.
- **Equilibrium** E**:** supply meets demand on the flat segment, so $R_D = R_A$. That is the first best: no agency wedge, and net worth is abundant enough that it does not constrain funding.

Why demand approaches $(1-\lambda)R_A$

- On the bent part of demand the incentive constraint binds, so

$$R_D \;=\; (1-\lambda)\,R_A\left(1+\frac{N}{D}\right).$$

- As deposits become large relative to net worth, skin in the game vanishes:

$$R_D \xrightarrow{D\to\infty} (1-\lambda)\,R_A.$$

- That floor is the **pledgeable** share of the asset return. The banker can divert fraction λ, so outside claims can be backed by at most $1-\lambda$. Once equity is negligible, no higher deposit rate is credible.
- In the high-N figure supply crosses before the kink, so the economy never uses this bent region. The floor matters when desired deposits exceed $\frac{1-\lambda}{\lambda}N$.

Appendix A7

Case 2: low net worth turns deposit demand downward

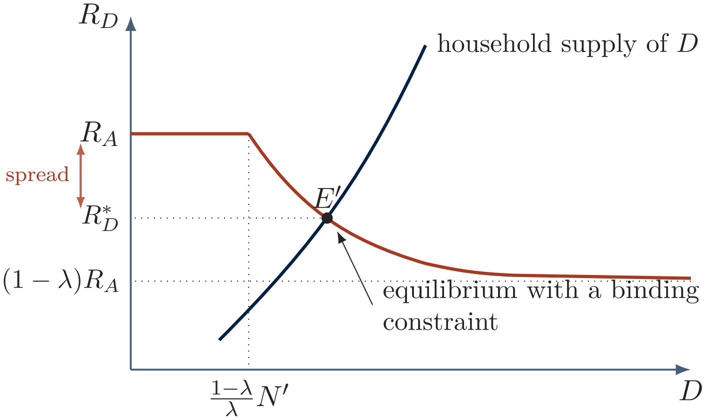
- If households want to save more than $\frac{1-\lambda}{\lambda}N$, (IC) binds: it holds with equality.
- Solving the equality for R_D (Appendix A7):

$$R_D = (1-\lambda)\, R_A \left(1 + \frac{N}{D}\right).$$

- Read: the more deposits the bank takes relative to its net worth, the stronger the temptation to abscond – so the rate the bank can *credibly* promise falls. Deposit demand slopes downward.
- No depositor needs to watch the banker. The promised rate itself is set so that honesty stays just barely worthwhile.

Appendix A7

With low net worth, credibility sets the deposit rate



The spread measures the shortage of net worth

- In the binding case $R_D < R_A$: a **spread** opens between what capital earns and what savers receive. Rearranging the binding constraint (Appendix A8):

$$\frac{R_A - R_D}{R_A} = \lambda - (1-\lambda)\,\frac{N}{D} > 0.$$

- Worked number (calibration used all through Part I: $R_A = 1.10$, $R_D = 1.04$, $\lambda = 0.15$; here $N = 10$, $D = 89$): spread $= 5.45\%$.
- Because savers receive less than capital produces, saving and lending are both below their efficient levels.
- Higher N shrinks the spread and pulls the economy back toward the first best – which is why post-2008 policy pushed so hard to recapitalise banks.

Appendix A8

One pound of net worth carries almost ten pounds of lending

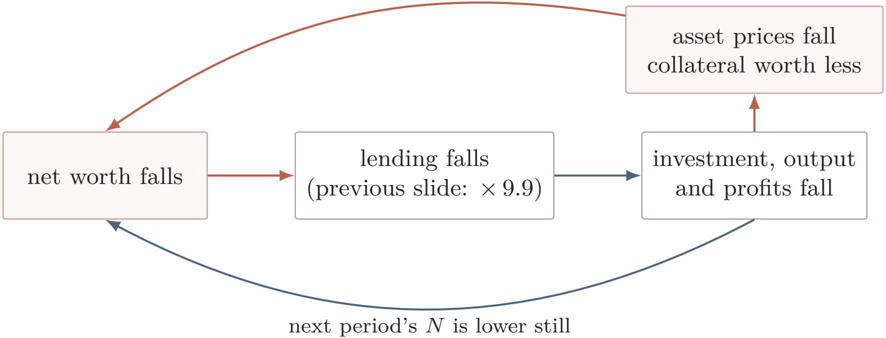
- Fix the rates and ask: how much outside funding does (IC) allow at most? Solving the binding equality for D (Appendix A9):

$$D^{\max} = \underbrace{\frac{(1-\lambda)R_A}{R_D-(1-\lambda)R_A}}_{\varphi} N, \qquad \text{when } R_D > (1-\lambda)R_A.$$

- φ**:** deposits allowed per unit of net worth – the funding multiple. Then $D^{\max} = \varphi N$, so deposit capacity scales one-for-one with equity.
- Calibration $R_A = 1.10$, $R_D = 1.04$, $\lambda = 0.15$: $\varphi = 0.935/0.105 = 8.90$. Lending capacity is $A = N + D^{\max} = (1+\varphi)N = 9.90\,N$: lose one pound of equity, lose almost ten pounds of lending.
- If R_D can adjust in equilibrium, the contraction is smaller (Appendix A10). The $\times 9.9$ figure is the sticky-rate case.

Appendix A9 Appendix A10

With more periods, the loss feeds on itself



- The **financial accelerator**: net worth is both an input to lending and an outcome of it, so shocks are amplified and prolonged.
- Falling asset prices cut the value of **collateral** – assets pledged as security for loans – and N falls again.

What Model 1 explains – and what it cannot

- Explains: lending capacity $\propto N$; the spread; recapitalisation as the remedy.
- These are **real financial frictions** – resources and incentives, not panic; present in normal times too (Baron, Verner and Xiong 2021).
- Cannot explain: a solvent bank dying in 48 hours. Nothing in this model moves in hours.

SVB's depositors did not slowly reprice trust; they queued. We need a model where time – not net worth – is the scarce thing.

Part II

Why can a bank die in a day?

What turns useful liquidity into a self-fulfilling panic?

The Diamond–Dybvig model: banks insure people against needing money early, and precisely that insurance supports a second equilibrium – the run.

The SVB run was a queue, not a repricing

- 94% of SVB's domestic deposits were uninsured (above the $250,000 limit).
- The top 0.5% of accounts – fewer than 500 depositors – held 38%; **74% of them ran by 17 March**. Insured retail balances stayed.
- Wires, not pavements: 1930 behaviour at 2023 speed. (Descriptive run rates, not causal estimates.)

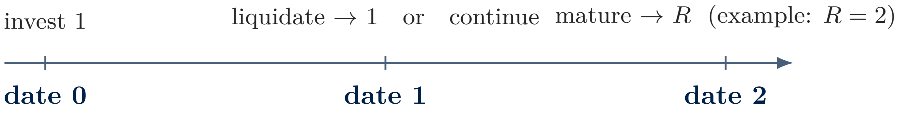
FDIC, *Dissecting Depositor Flight*, May 2026.

Diamond–Dybvig: banks as insurers that can be run

- Diamond and Dybvig (1983); Nobel prize 2022. Two predictions that live together:
  - banks create **liquidity** – the ability to be paid *now* – and raise welfare;
  - precisely because of that, a run equilibrium also exists.
- The engine is **maturity mismatch**: assets that pay later stand behind promises callable today.
- Built in the same three moves as Model 1: actors, choices, equilibrium.

Three dates, one illiquid technology

- Fresh model, fresh notation: R and θ now mean what *this* model says.
- Dates 0, 1, 2. Many identical people, each with 1 unit at date 0.
- Invest 1 at date 0 $\rightarrow R > 1$ at date 2; **liquidate** at date 1 $\rightarrow$ only 1. Storage between dates is free.
- Investment dominates storage, so everyone invests everything.



Impatience arrives after the investment is made

- At date 1 each person learns their type – written as a superscript:
  - type a, **impatient**, probability θ: only date-1 consumption has value, $U^a = \ln c_1^a$;
  - type b, **patient**, probability $1-\theta$: date-1 and date-2 consumption are perfect substitutes, $U^b = \rho \ln(c_1^b + c_2^b)$.
- $\rho \in (0,1)$, and we assume $\rho R > 1$: it will earn its keep twice – at the optimum, and at the good equilibrium.
- Your type is **private information**: nobody else can verify it.
- "Impatience" stands for any sudden need for money: the roof leaks, the firm must pay wages, an opportunity appears.

Alone, everyone self-insures badly

- **Autarky**: no bank and no trading; each person simply holds their own investment and reacts to their type.
  - impatient: liquidate at date 1 and consume 1;
  - patient: hold to date 2 and consume R.
- Expected utility, seen from date 0:

$$\mathbb{E}[U^{\text{autarky}}] \;=\; \theta \ln 1 + (1-\theta)\,\rho \ln R \;=\; (1-\theta)\,\rho \ln R.$$

- Running example for the whole model: $(\theta, \rho, R) = \left(\frac{1}{3}, \frac{3}{4}, 2\right)$. In autarky the unlucky consume 1, the lucky consume 2.
- Would a market for claims on future goods help? No: prices settle at 1 and $1/R$, and at those prices nobody trades – the outcome is autarky again (Appendix B1).

Appendix B1

A planner would share the liquidation burden

- Thought experiment: a **social planner** who can observe types and reallocate goods – the benchmark for the best feasible outcome.
- The planner gives c_1^a to each impatient person and c_2^b to each patient one, and nothing else:
  - date-2 goods are worthless to the impatient;
  - goods left invested grow at $R > 1$, so the patient are served at date 2.
- The planner maximises expected utility subject to resources:

$$\max_{c_1^a,\, c_2^b} \; \theta \ln c_1^a + (1-\theta)\, \rho \ln c_2^b \qquad \text{s.t.} \qquad (1-\theta)\, c_2^b = \left(1 - \theta c_1^a\right) R.$$

θc_1^a = the share of projects liquidated at date 1 to feed the impatient; whatever is not liquidated matures at R.

Appendix B2

The optimum gives the unlucky more than their savings

- Substituting the constraint and taking the first-order condition gives the **first-best allocation** (stars mark optimal values; type superscripts are dropped – only the impatient consume at date 1, only the patient at date 2):

$$c_1^* = \frac{1}{\theta + (1-\theta)\rho} > 1, \qquad c_2^* = \frac{\rho R}{\theta + (1-\theta)\rho} < R.$$

- Three checks, each proven in Appendix B3:
  - $c_1^* > 1$ because $\rho < 1$: the planner liquidates *more* than autarky would, to feed the unlucky;
  - $c_2^* < R$: the lucky give up a little;
  - $c_2^* > c_1^*$ exactly when $\rho R > 1$ – the assumption earns its keep for the first time.
- Running example: $c_1^* = 1.2$ and $c_2^* = 1.8$, against autarky's 1 and 2 (arithmetic end to end: Appendix B4).

Appendix B3 Appendix B4

This is insurance against being unlucky early

- Impatient: $1 \to 1.2$. Patient: $2 \to 1.8$. A transfer across luck – precisely **insurance**. Ex ante, everyone prefers it.
- No private insurer can sell it: types are private, so everyone would claim impatience. The market is **missing**.
- Yet no planner is needed – Diamond and Dybvig's first insight.

A demand deposit implements the optimum

- The contract: deposit 1 at date 0; withdraw c_1^* **on demand** at date 1, no questions asked; the date-2 remainder is shared equally among those who waited.
- The bank invests everything and liquidates just enough to pay whoever arrives.
- Nobody's type is checked: the contract lets people sort themselves – if beliefs cooperate.

If only the impatient withdraw, the promise keeps itself

- If exactly the share θ withdraws, each waiter receives

$$c_2 \;=\; \frac{(1-\theta c_1^*)R}{1-\theta} \;=\; c_2^* \qquad \text{(example: } \tfrac{0.6\times 2}{2/3} = 1.8\text{)}.$$

- A **Nash equilibrium**: given what others do, nobody gains by changing their move.
  - Impatient must withdraw; patient wait, since withdraw-and-store gives $1.2 < 1.8$ (storage and $\rho R > 1$ cash in here);
  - at date 0, depositing beats autarky: $0.355 > 0.347$ (B5).
- Banks are socially useful: the contract manufactures the missing insurance.

Appendix B5

The bank has promised more than it can liquidate

- Everyone holds the right to $c_1^* = 1.2$ at date 1; liquidating *everything* raises only 1 per depositor.
- **Sequential service**: paid in full, in order of arrival, until the money runs out; queue positions are random.
- If all withdraw, only $1/c_1^* = 5/6$ are served. The last sixth get nothing.

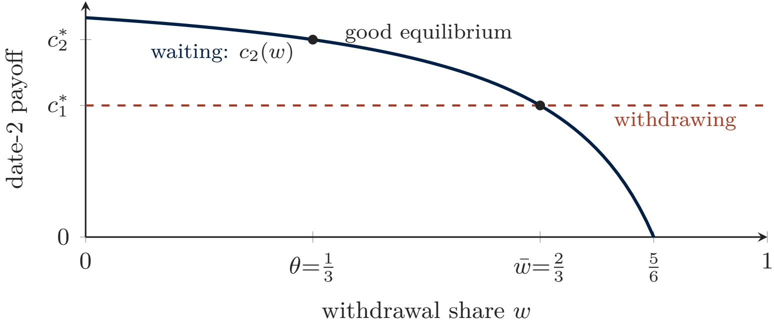
“Everyone runs” is also an equilibrium

- If every patient depositor expects a run: waiting yields 0; joining yields c_1^* with probability 5/6. A chance of something beats the certainty of nothing.
- So running is the best reply to a run: the belief **fulfils itself**. No fundamental changed – a rumour is enough.
- Deposit at date 0 anyway? Yes, if runs are unlikely enough (B6).

Appendix B6

Beliefs pick one of two resting points

- Let w = the share who withdraw at date 1. Waiting pays $c_2(w) = \dfrac{(1 - w\,c_1^*)R}{1-w}$, falling in w; withdrawing pays c_1^* while funds last (derivation: B7).



- Left of $\bar{w} = 2/3$ waiting wins; right of it running wins; beyond $5/6$ the till is empty.

Appendix B7

Three markers on the horizontal axis

- **$\theta = \frac{1}{3}$:** only the truly impatient withdraw. Waiting still pays $c_2^* = 1.8 > 1.2$. This is the **good equilibrium**.
- **$\bar{w} = \frac{2}{3}$:** the tipping point where $c_2(w) = c_1^*$. Left of it, waiting beats withdrawing; right of it, running beats waiting.
- **$\frac{5}{6} = 1/c_1^*$:** the largest share the bank can pay in full. Liquidating everything raises only 1 per depositor, but each claim is 1.2, so at most 1/1.2 are served. Beyond this the till is empty.

Same bank, two resting points – beliefs choose

- The curves do not change. What changes is expected w: how many others you think will withdraw today.
- If you expect w near θ, waiting pays more than running, so patient people wait – and that expectation is confirmed.
- If you expect w past $\bar{w}$, waiting looks worthless, so patient people run – and that expectation is also confirmed.
- That is the Diamond–Dybvig message: the insurance contract that delivers $c_1^* > 1$ also creates a self-fulfilling run. Fragility is not a bug added on top; it is the price of the liquidity promise.

Fragility is the price of liquidity insurance

- One number carries the story: $c_1^* > 1$ *is* the insurance, and *is* the vulnerability – more promised today than assets can raise today.
- In a run the bank is **solvent but illiquid**: held to date 2, its assets cover every promise.
  - And the run outcome ranks below autarky: banking creates the possibility of something worse than no bank at all.
- Every assumption did a named job: liquidation value (feasibility), storage (outside option), $\rho < 1$ (insurance direction), $\rho R > 1$ (waiting), private types (missing market).

You cannot remove the run without touching the insurance – unless someone changes the game itself. Enter policy.

Part III

What kills a run?

Can policy delete the bad equilibrium and keep the good one?

Three classic instruments – suspension, the lender of last resort, and deposit insurance – each judged by one test: does running stop being a best reply?

Policy 1: stop paying after a fraction θ has withdrawn

- One test for every policy: does running stop being a best reply?
- **Suspension of convertibility**: pay c_1^* to at most a fraction θ, then suspend until date 2.
- Whoever waits is then *sure* of $c_2^* > c_1^*$ (C1): the run equilibrium disappears. Nineteenth-century practice.
- Two weaknesses:
  - if the impatient share is uncertain, the cap can shut out people in genuine need;
  - an insolvent bank can hide behind suspension.

Appendix C1

Policy 2: lend the bank its own tomorrow

- **Lender of last resort**: the central bank lends at date 1 against date-2 assets, at gross rate $c_2^*/c_1^* = \rho R = 1.5$.
- If a share $w > \theta$ withdraws: liquidate θc_1^*, borrow $(w - \theta)\, c_1^*$, repay $(w - \theta)\, c_2^*$ – and every waiter still gets c_2^* (C2). So the run never starts.
- Financed by taxation – or money creation: printing raises date-1 prices, and early withdrawers pay in real terms. Inflation is the tax.

Appendix C2

Bagehot's dictum, and what the model says about it

- Bagehot (1873): lend *freely*, on *good collateral*, at a *penalty rate*.
- The model delivers the first two; but its rate $\rho R = 1.5$ is below the market return $R = 2$ – a discount, not a penalty.
- Cheap lending invites borrowing instead of liquidating. The fix: a **reserve requirement** – liquidate your own θ share first.
- 2023: the Fed's emergency facility lent against bonds at par, no penalty. The old debate reopened.

Policy 3: a guarantee that works because it is never used

- **Deposit insurance**: the government guarantees c_2^* to everyone who waits – financed, if ever needed, by a tax on early withdrawers (C3).
- Waiting now pays c_2^* whatever others believe or do: running is never a best reply. The run equilibrium is deleted, not just discouraged.
- Since nobody runs, the guarantee never pays and the tax is never levied: an **off-equilibrium promise**.

Appendix C3

The 1930s built it; 2023 stress-tested it

- 1933: the FDIC, after thousands of failures. Retail runs on insured deposits all but disappeared for ninety years.
- 2023: SVB was 94% *un*insured – the run happened where the promise did not reach.
- Ex post, a systemic-risk exception guaranteed everyone; the insurance fund booked \$16.7bn.
- Insurance deletes runs where it applies; panics migrate to where it does not.

FDIC, *Dissecting Depositor Flight*, May 2026.

One balance sheet, two failure modes, two models

	Model 1: net worth	**Model 2: liquidity**
question	how much can the bank lend?	can the bank survive its depositors' beliefs?
failure mode	erosion of N: spread opens, lending shrinks	self-fulfilling withdrawal: solvent bank dies at date 1
speed	quarters to years	hours to days
policy family	recapitalisation, capital rules	suspension, lender of last resort, deposit insurance

- In practice the two mix: losses weaken fundamentals, and weak fundamentals make the run equilibrium easier for beliefs to select.

The SVB answer – and what comes next

- A Model-1 wound: rate rises had cut the value of SVB's bond portfolio – real, but survivable.
- A Model-2 death: 94% uninsured, concentrated, wired – on 9 March, beliefs selected the run.
- The run-deleting guarantee arrived two days *after* the run; when it arrived, the panic stopped. Exactly what the model predicts.
- Next time: what guarantees themselves do to risk-taking.

A bank can die of losses, and it can die of time. Policy must diagnose before it prescribes.

Technical appendix: derivation map

Toolkit

- T1 – the two derivatives used today
- T2 – optimisation by substitution

Part I – the lending model

- A1 – Euler equation, step by step
- A2 – why deposit supply slopes up
- A3 – solving the household system
- A4 – the benchmark allocation
- A5 – why no-default is without loss
- A6 – the slack-case threshold
- A7 – the downward demand curve
- A8 – the spread formula
- A9 – capacity and the multiplier
- A10 – a fully solved equilibrium

Part II – Diamond–Dybvig

- B1 – a claims market changes nothing
- B2 – planner solution, step by step
- B3 – the three inequalities
- B4 – the running example end to end
- B5 – the good equilibrium, verified
- B6 – run arithmetic
- B7 – the two-equilibria picture

Part III – policies

- C1 – suspension arithmetic
- C2 – lender of last resort, line by line
- C3 – the off-equilibrium tax

Back to lecture

T1 – the only two derivatives used today

- Square root. Write $\sqrt{c} = c^{1/2}$ and use the power rule:

$$\frac{d}{dc}\sqrt{c} \;=\; \tfrac{1}{2}\,c^{-1/2} \;=\; \frac{1}{2\sqrt{c}}.$$

  Positive (more is better) and decreasing in c (each unit adds less): exactly the diminishing marginal utility we wanted.

- Natural logarithm:

$$\frac{d}{dc}\ln c \;=\; \frac{1}{c}.$$

  Same two properties, same interpretation.

- Chain rule, the one composite we need. If $c_1 = y - D$, then

$$\frac{d}{dD}\sqrt{y-D} \;=\; \frac{1}{2\sqrt{y-D}} \times (-1) \;=\; -\frac{1}{2\sqrt{c_1}},$$

  and likewise $\frac{d}{dD}\sqrt{R_D D + \pi} = \frac{R_D}{2\sqrt{c_2}}$.

Back to lecture

T2 – constrained optimisation by substitution

- Our problems all have the same shape: maximise an objective subject to equality constraints (budgets, resources).
- The substitution method:
  1. use each constraint to express one variable in terms of the others (for example $c_1 = y - D$);
  2. substitute into the objective, leaving a function of one free variable;
  3. set its derivative to zero – the first-order condition (FOC).
- Why "derivative equals zero": at a maximum, no tiny feasible move can raise the objective; if the derivative were positive or negative, some tiny move would.
- Fine print we rely on and state once: our objectives are strictly concave, so the FOC finds the unique maximum, and solutions are interior (a little of both consumptions is always better than none – marginal utility explodes near zero).

Back to lecture

A1 – the Euler equation, step by step

- Substitute both budgets into the utility function:

$$U(D) \;=\; \sqrt{y-D} \;+\; \beta\sqrt{R_D D+\pi}\,.$$

- Differentiate with respect to D (chain rule, T1):

$$U'(D) \;=\; -\,\frac{1}{2\sqrt{y-D}} \;+\; \beta\,\frac{R_D}{2\sqrt{R_D D+\pi}}.$$

- Set $U'(D)=0$, multiply both sides by 2, and recognise the budgets ($c_1 = y-D$, $c_2 = R_D D+\pi$):

$$\frac{1}{\sqrt{c_1}} \;=\; \beta R_D\,\frac{1}{\sqrt{c_2}}.$$

- Rearrange: multiply both sides by $\sqrt{c_2}$, then square:

$$\sqrt{c_2} = \beta R_D\sqrt{c_1} \qquad \Longrightarrow \qquad c_2 = (\beta R_D)^2\,c_1\,.$$

Back to lecture

A2 – why deposit supply slopes upward

- A higher R_D pulls the household in two directions at once:
  - **substitution effect**: consumption today has become more expensive in tomorrow-units (each unit not saved forgoes more), so consume less today – save *more*;
  - **income effect**: a saver is richer at a higher rate, and richer people want more of everything, including consumption today – save *less*.
- With $\sqrt{c}$ utility the substitution effect wins. Since $D = y - c_1$, differentiate $c_1 = \dfrac{y + \pi/R_D}{1 + \beta^2 R_D}$ by the quotient rule:
$$\frac{dc_1}{dR_D} = \frac{(-\pi/R_D^2)(1 + \beta^2 R_D) - (y + \pi/R_D)\,\beta^2}{(1 + \beta^2 R_D)^2},$$
multiply top and bottom by R_D^2 and collect terms: the numerator becomes $-\big(\beta^2 R_D^2 y + 2\beta^2 R_D \pi + \pi\big) < 0$, every term positive. So c_1 falls, and $D = y - c_1$ rises with R_D, always.
- Deeper reason, for reference: $\sqrt{c}$ has an elasticity of intertemporal substitution of 2, above the knife-edge value 1 at which the two effects cancel (log utility).

Back to lecture

A3 – solving the household system

- The three equations: (i) $c_1 + D = y$; (ii) $c_2 = R_D D + \pi$; (iii) $c_2 = (\beta R_D)^2 c_1$.
- Substitute (i) into (ii) to remove D:

$$c_2 \;=\; R_D\,(y - c_1) + \pi.$$

- Set this equal to (iii):

$$(\beta R_D)^2 c_1 \;=\; R_D\,y - R_D\,c_1 + \pi.$$

- Collect the c_1 terms and divide:

$$c_1\left(\beta^2 R_D^2 + R_D\right) = R_D\,y + \pi$$

$$c_1 \;=\; \frac{R_D\,y + \pi}{R_D\,(1 + \beta^2 R_D)} = \frac{y + \pi/R_D}{1 + \beta^2 R_D}.$$

- Then $D = y - c_1$ and $c_2 = R_D D + \pi$ follow. Interior check: $D > 0$ whenever $\pi < \beta^2 R_D^2\,y$ – true in every calibration used today.

Back to lecture

A4 – the benchmark allocation in full

- In the benchmark, $R_D = R_A$ and $\pi = NR_A$. Then $\pi/R_D = NR_A/R_A = N$, so the household solution collapses to

$$c_1 \;=\; \frac{y+N}{1+\beta^2 R_A}, \qquad D = y - c_1, \qquad c_2 \;=\; R_A D + NR_A \;=\; R_A\,(N+D) \;=\; R_A\,A.$$

- Read the last equality: period-2 consumption is exactly what the economy's investment produces. Nothing leaks.
- Why this is first-best: the household's reward for waiting (R_D) equals the technology's true rate of transformation (R_A).
  - A planner maximising the same utility subject to the economy's resource constraint would impose exactly this trade-off, so market and planner agree.
- Banks here are a perfect pipe: every saved unit reaches the productive technology and returns in full.

Back to lecture

A5 – why studying no-default equilibria loses nothing

- Suppose there were an equilibrium in which banks default at date 2. Depositors collectively receive $(1-\lambda)R_A(N+D)$, so the *effective* return per unit deposited is

$$R^{\text{eff}} = \frac{(1-\lambda)\,R_A\,(N+D)}{D}.$$

- Rational households foresee the default, so their saving decision is based on R^{eff}, not the empty promise R_D.
- Now build a twin equilibrium: promise $R'_D = R^{\text{eff}}$ honestly.
  - Households face the same effective return, so they choose the same D;
  - the incentive constraint holds with equality under R'_D:

$$(N+D)R_A - R'_D D \;=\; (N+D)R_A - (1-\lambda)R_A(N+D) \;=\; \lambda R_A(N+D).$$

- Same allocation, no default. So restricting attention to no-default equilibria discards no outcomes – only bookkeeping.

Back to lecture

A6 – the slack-case threshold, three lines

- Substitute $R_D = R_A$ into (IC):

$$(N + D)\, R_A - R_A\, D \;\geq\; \lambda\, R_A\, (N + D).$$

- The left side simplifies – the $R_A D$ terms cancel:

$$N\, R_A \;\geq\; \lambda\, R_A\, (N + D) \qquad \Longrightarrow \qquad N \;\geq\; \lambda\, (N + D).$$

- Collect N on the left and divide by λ:

$$N\, (1 - \lambda) \;\geq\; \lambda\, D \qquad \Longrightarrow \qquad D \;\leq\; \frac{1 - \lambda}{\lambda}\, N.$$

- With $\lambda = 0.15$ the multiple is $0.85/0.15 = 5.67$.
- Equivalent reading: $N \geq \lambda A$ – net worth must be at least the divertable share of the balance sheet. A capital requirement, derived rather than assumed.

Back to lecture

A7 – the downward-sloping demand curve

- When (IC) binds it holds with equality:

$$(N+D)\,R_A - R_D\,D \;=\; \lambda\,R_A\,(N+D).$$

- Move the deposit bill to one side:

$$R_D\,D \;=\; (1-\lambda)\,R_A\,(N+D).$$

  In words: the whole promised repayment must fit inside the non-divertable part of the bank's earnings.

- Divide by D:

$$R_D \;=\; (1-\lambda)\,R_A\left(1+\frac{N}{D}\right).$$

- Shape: $\dfrac{dR_D}{dD} = -(1-\lambda)R_A\dfrac{N}{D^2} < 0$, and as $D \to \infty$ the curve flattens toward $(1-\lambda)R_A$ – the dotted floor in the diagrams.
- Economics of the slope: each extra deposit dilutes the banker's own stake, strengthens the temptation, and so shrinks the rate that can be promised credibly.

Back to lecture

A8 – the spread formula

- Start from the binding demand curve (A7), $R_D = (1-\lambda)R_A\,(1 + N/D)$, and compute the proportional spread:

$$\frac{R_A - R_D}{R_A} = 1 - (1-\lambda)\left(1 + \frac{N}{D}\right)$$
$$= 1 - (1-\lambda) - (1-\lambda)\frac{N}{D}$$
$$= \lambda - (1-\lambda)\,\frac{N}{D}.$$

- Sign: positive exactly when $D > \frac{1-\lambda}{\lambda}N$ – which is precisely the binding region. Slack region: spread zero. The two cases join with no gap at the threshold.
- Numbers ($\lambda = 0.15$, $N = 10$, $D = 89$):

$$0.15 - 0.85 \times \tfrac{10}{89} \;=\; 0.15 - 0.0955 \;=\; 0.0545 \;=\; 5.45\%,$$

matching $(1.10 - 1.04)/1.10$ directly.

- More net worth, or less divertibility, shrinks the spread.

Back to lecture

A9 – funding capacity and the multiplier

- Solve the binding equality for D instead of R_D. From $R_D D = (1-\lambda)R_A(N+D)$:

$$D\left[R_D - (1-\lambda)R_A\right] = (1-\lambda)R_A\,N \qquad \Longrightarrow \qquad D^{\max} = \frac{(1-\lambda)R_A}{R_D-(1-\lambda)R_A}\,N.$$

- Validity: the denominator must be positive, $R_D > (1-\lambda)R_A$; otherwise honest earnings outgrow promises forever and no finite limit exists.
  - The formula needs *gross* returns: net rates (0.04, 0.10) flip the denominator's sign and produce nonsense.

- Calibration $R_A = 1.10$, $R_D = 1.04$, $\lambda = 0.15$:

$$\varphi = \frac{0.85\times 1.10}{1.04-0.85\times 1.10} = \frac{0.935}{0.105} = 8.90.$$

- So $\Delta D^{\max} = 8.90\,\Delta N$, and lending $A = N + D^{\max}$ moves by $1+\varphi = 9.90$ per unit of net worth. This is the leverage arithmetic behind "repair the banks first".

Back to lecture

A10 – one fully solved equilibrium, both regimes

- Parameters: $y = 20$, $\beta = 0.95$, $\lambda = 0.15$, $R_A = 1.10$; only N differs.

	$N = 2$ **(slack)**	$N = 1$ **(binding)**
threshold $\frac{1-\lambda}{\lambda}N$	11.33	5.67
deposit rate R_D^*	1.10 $(= R_A)$	1.0403
profit π^*	2.20	1.63
consumption c_1^*	11.04	11.12
deposits D^*	8.96	8.88
spread $(R_A - R_D^*)/R_A$	0	5.4%

- Slack column: supply at $R_D = R_A$ gives $D = 8.96 < 11.33$, so the constraint indeed never binds – first best.
- Binding column: solving supply against the binding demand curve, with $\pi = \lambda R_A(N + D)$, gives $D^* = 8.88$ at $R_D^* = 1.0403$.
- Equilibrium damping: here $dD^*/dN \approx 0.5$, far below $\varphi = 8.9$, because supply is steep – lost net worth shows up mainly in the deposit rate. The capacity multiplier is the upper bound, reached when rates cannot adjust.

Back to lecture

B1 – a market for claims would change nothing

- Let agents trade claims on future goods at date 1 (after types are known) and at date 0. Prices are pinned by arbitrage against the technology:
  - at date 1, a claim on one date-2 good must cost $1/R$: dearer, and impatient sellers would find no buyers (anyone can create date-2 goods at rate R by not liquidating); cheaper, and patient buyers would find no sellers (liquidating to buy claims would beat holding);
  - at date 0, by the same logic, date-1 goods cost 1 and date-2 goods cost $1/R$.
- At those prices, an impatient agent's investment is worth exactly 1 at date 1, and a patient agent's exactly R at date 2 – the autarky payoffs.
- And at date 0 all agents are identical, so no trade happens at all.
- Conclusion: competitive markets replicate autarky here. The missing piece is insurance against *which type you turn out to be* – and that market cannot exist while types are private.

Back to lecture

B2 – the planner's solution, step by step

- Solve the resource constraint for c_2^b:

$$c_2^b = \frac{(1-\theta c_1^a)\,R}{1-\theta}, \qquad \text{so} \qquad \frac{dc_2^b}{dc_1^a} = -\frac{\theta R}{1-\theta}.$$

- Substitute into the objective $W = \theta \ln c_1^a + (1-\theta)\rho \ln c_2^b$ and differentiate (chain rule on the log, T1):

$$\frac{dW}{dc_1^a} = \frac{\theta}{c_1^a} + (1-\theta)\rho \cdot \frac{1}{c_2^b} \cdot \left(-\frac{\theta R}{1-\theta}\right) = \frac{\theta}{c_1^a} - \frac{\rho\,\theta R}{c_2^b}.$$

- Set to zero and cancel θ:

$$c_2^b = \rho R\, c_1^a \qquad \text{(the planner's own Euler-like condition).}$$

- Combine with the resource constraint:

$$(1-\theta)\,\rho R\, c_1^a = (1-\theta c_1^a)R \implies c_1^a\left[\theta + (1-\theta)\rho\right] = 1 \implies c_1^* = \frac{1}{\theta + (1-\theta)\rho},$$

and then $c_2^* = \rho R\, c_1^*$.

Back to lecture

B3 – the three inequalities, each proven

- $c_1^* > 1$. The denominator is a weighted average of 1 and ρ:

$$\theta + (1-\theta)\rho \;<\; \theta + (1-\theta) \;=\; 1 \quad \text{because } \rho < 1,$$

  so its reciprocal exceeds 1. It is $\rho < 1$ – the impatient valuing consumption more – that pushes insurance their way.

- $c_2^* < R$. Divide $c_2^* = \rho R/(\theta + (1-\theta)\rho)$ by R and compare:

$$\rho \;<\; \theta + (1-\theta)\rho \iff \rho\theta \;<\; \theta \iff \rho < 1.\checkmark$$

- $c_2^* > c_1^*$ **exactly when** $\rho R > 1$. Immediate from the planner's condition $c_2^* = \rho R\, c_1^*$ (B2).
  - This is the inequality that will keep patient depositors waiting in the good equilibrium – the model's incentive-compatibility linchpin.

Back to lecture

B4 – the running example, end to end

- Parameters: $\theta = \frac{1}{3}$, $\rho = \frac{3}{4}$, $R = 2$; check $\rho R = 1.5 > 1$. ✓
- Denominator: $\theta + (1-\theta)\rho = \frac{1}{3} + \frac{2}{3} \times \frac{3}{4} = \frac{1}{3} + \frac{1}{2} = \frac{5}{6}$.
- Allocation:
$$c_1^* = \frac{6}{5} = 1.2, \qquad c_2^* = \rho R\, c_1^* = 1.5 \times 1.2 = 1.8.$$
- Resource check: liquidate $\theta c_1^* = 0.4$; the remaining 0.6 matures to $0.6 \times 2 = 1.2$; shared among $1 - \theta = \frac{2}{3}$ of agents: $1.2/\frac{2}{3} = 1.8 = c_2^*$. ✓
- Welfare against autarky:
$$\mathbb{E}[U^{\text{bank}}] = \frac{1}{3} \ln 1.2 + \frac{2}{3} \times \frac{3}{4} \ln 1.8 = 0.3547$$
$$\mathbb{E}[U^{\text{autarky}}] = \frac{2}{3} \times \frac{3}{4} \ln 2 = 0.3466.$$

  The insurance is worth having: $0.3547 > 0.3466$.

Back to lecture

B5 – the good equilibrium, verified in full

- **The identity.** If exactly the share θ withdraws c_1^*, each waiter gets

$$\frac{(1-\theta c_1^*)R}{1-\theta} = \frac{\left(1-\frac{\theta}{\theta+(1-\theta)\rho}\right)R}{1-\theta} = \frac{(1-\theta)\rho}{\theta+(1-\theta)\rho}\cdot\frac{R}{1-\theta} = \rho R\, c_1^* = c_2^*.\checkmark$$

- **Nobody deviates**, checked type by type:
  - impatient: date-2 goods are worthless to them, so they withdraw – no deviation to test;
  - patient, deviation "withdraw early and store": receive $c_1^* = 1.2$ at date 1, store it, consume 1.2 at date 2 – worse than waiting for $c_2^* = 1.8$ since $\rho R > 1$;
  - date-0 participation: depositing yields expected utility 0.3547, autarky 0.3466 (B4) – everyone deposits.
- So "deposit; withdraw only if impatient" is a Nash equilibrium, and it delivers the planner's first-best allocation with no planner.

Back to lecture

B6 – run arithmetic

- Suppose everyone withdraws ($w = 1$). The bank liquidates everything: 1 unit per depositor against promises of $c_1^* = 1.2$ each.
- Sequential service with random queue positions: the bank serves the first $1/c_1^* = 5/6$ of the queue in full; the remaining $1/6$ receive nothing.
  - Sanity check: $\frac{5}{6} \times 1.2 = 1$, the whole liquidation value, distributed. ✓
- Given the run, a patient depositor compares:
  - wait: 0 with certainty (nothing survives to date 2);
  - join: 1.2 with probability $5/6$, else 0.

  Joining wins for any utility function: the run is a Nash equilibrium.
- Why deposit at date 0 at all? With a small run probability, and utility bounded at zero consumption (a subsistence floor), the insurance gain outweighs the small risk. With unbounded ln at zero the comparison needs that floor – a technical clause, stated honestly.

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B7 – the two-equilibria picture, derived

- Let a share w withdraw at date 1. The bank liquidates $w\,c_1^*$; the rest matures; each of the $1-w$ waiters receives

$$c_2(w) \;=\; \frac{\left(1 - w\,c_1^*\right)R}{1-w}.$$

- Slope: the derivative's numerator is $R\big[(1-w)\cdot(-c_1^*) + (1-w\,c_1^*)\big] = R\,(1-c_1^*) < 0$ since $c_1^* > 1$: each extra withdrawer removes more than they release, so waiting pays less. Falling, always.
- The threshold $\bar{w}$ where waiting stops beating withdrawing solves $c_2(\bar{w}) = c_1^*$:

$$(1-\bar{w}c_1^*)R = c_1^*(1-\bar{w}) \implies \bar{w} \;=\; \frac{R-c_1^*}{c_1^*\,(R-1)} \;=\; \frac{2-1.2}{1.2\times 1} = \frac{2}{3}.$$

- Funds run out at $w = 1/c_1^* = 5/6$: beyond it, $c_2(w)$ has hit zero and latecomers at date 1 are already unpaid.
- Endpoints of the picture: at $w=\theta$ waiting pays $c_2^* = 1.8 > 1.2$ (good equilibrium); at $w=1$ waiting pays 0 (run).

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C1 – suspension arithmetic

- The clause: pay c_1^* to at most a fraction θ of depositors at date 1, then suspend.
- Maximum possible liquidation is therefore $\theta c_1^* = 0.4$, so at least

$$(1 - \theta c_1^*)\, R \;=\; 0.6 \times 2 \;=\; 1.2$$

  of date-2 value is preserved – whatever people attempt at date 1.
- Suppose a share $w > \theta$ tries to withdraw. Only θ are paid; the disappointed join the waiters; the preserved 1.2 is shared among at least $1 - \theta = \frac{2}{3}$, giving at most... exactly $c_2^* = 1.8$ each when the impatient share is truly θ.
- A patient depositor therefore gets $c_2^* = 1.8$ by waiting, with certainty, against at most $c_1^* = 1.2$ by running: nobody patient ever runs. The run equilibrium is gone.
- The two failure modes on the main slide, now visible in the algebra: if the true impatient share exceeds θ, the cap denies payment to genuinely impatient people (who value date-2 goods at nothing); and the clause protects an insolvent bank exactly as well as a solvent one.

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C2 – the lender of last resort, line by line

- Central bank offer: lend at date 1 against date-2 assets at gross rate $c_2^*/c_1^* = \rho R = 1.5$.
- Take $w = \frac{1}{2} > \theta = \frac{1}{3}$ withdrawing in the running example:
  - liquidate as planned: $\theta c_1^* = 0.4$ pays the first third;
  - borrow $(w - \theta)\, c_1^* = \frac{1}{6} \times 1.2 = 0.2$ to pay the rest of the withdrawers;
  - date 2 arrives: matured assets are $(1 - \theta c_1^*)R = 1.2$;
  - repay the central bank $(w - \theta)\, c_1^* \times \rho R = (w - \theta)\, c_2^* = 0.3$;
  - residual $1.2 - 0.3 = 0.9$, shared among the $1 - w = \frac{1}{2}$ who waited: $0.9/0.5 = 1.8 = c_2^*$ each. ✓
- The identity behind the example, for any w: $(1 - \theta c_1^*)R - (w - \theta)c_2^* = (1 - w)\, c_2^*$. Waiters always get c_2^*; so nobody patient runs, and the loan is never actually needed in equilibrium.
- The rate $\rho R = 1.5$ is below the market return $R = 2$: lending at a discount. Hence the moral hazard and the reserve-requirement clause on the Bagehot slide.

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C3 – deposit insurance and the off-equilibrium tax

- The guarantee: whoever waits until date 2 receives c_2^*, full stop.
- What would happen if a share $w > \theta$ withdrew anyway:
  - the bank's date-2 resources, $(1 - w\, c_1^*)R$, would fall short of the guaranteed $(1 - w)\, c_2^*$;
  - the government would top up the difference, financed by a **tax** on the w early withdrawers – clawing back part of the c_1^* they took out;
  - early withdrawal in a panic therefore pays *less* than c_1^*, while waiting still pays c_2^* in full.
- So for a patient depositor, waiting dominates *unconditionally*: $c_2^* = 1.8$ for sure, against at most 1.2 (and less, after tax, in a panic). Running is never a best reply.
- Therefore $w = \theta$ always: the bank's own resources suffice, the guarantee pays nothing, the tax is never levied. The promise does all the work without ever acting.

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Sources and further material

Models

- Diamond, D. and P. Dybvig (1983), "Bank Runs, Deposit Insurance, and Liquidity", *Journal of Political Economy* 91(3).
- Gertler, M. and P. Karadi (2011), "A Model of Unconventional Monetary Policy", *Journal of Monetary Economics* 58(1).
- Gertler, M. and N. Kiyotaki (2015), "Banking, Liquidity, and Bank Runs in an Infinite Horizon Economy", *American Economic Review* 105(7).
- Bagehot, W. (1873), *Lombard Street: A Description of the Money Market.*

Evidence and events

- Baron, M., E. Verner and W. Xiong (2021), "Banking Crises Without Panics", *Quarterly Journal of Economics* 136(1).
- Laeven, L. and F. Valencia (2018), *Systemic Banking Crises Revisited*, IMF Working Paper 18/206.
- FDIC, *Dissecting Depositor Flight*, May 2026. Federal Reserve, *Review of the Federal Reserve's Supervision and Regulation of Silicon Valley Bank*, April 2023.

Further viewing

- The power of bad news: a bank run on film (YouTube)
- Regulation is not bureaucracy (YouTube)

Appendix map