Economics 1011B
Section 7

Spring 2023

Today's Outline

- Motivation
  - Liquidity
  - Bank Runs
- Model of Bank Runs (Diamond and Dybvig)
  - Depositors
  - Investment
  - Autarky vs. Social Planner
  - Banks to the Rescue...
  - ... But Maybe Not (Bank Runs)
- Bonus Slides: Financial Frictions

Motivation

- Banks and bank-like institutions pervasive in the modern economy.
- Why do banks exist? (same reason any other firm exists)
- What do banks do that can be good? At a high level:
    1. Intermediary between savers and borrowers
    2. Distribute risk of investing across agents
    3. Provide financial services to savers and borrowers
    4. Allocate capital (hopefully, to efficient uses)
- Today, we'll focus on the first role: banks as a financial intermediary, an agent that connects buyers in sellers (in this case, for savings).

Liquidity

- What is liquidity? A property of markets (and in particular, asset markets).
- A liquid asset is easy and inexpensive to convert into cash; an illiquid asset is hard and/or expensive to convert into cash.
- Generally speaking, banks issue liquid liabilities and invest in illiquid assets. Bank deposits are liabilities from the bank's perspective, and they can move quickly (liquid).
- Distinctions between types of banks (i.e. hedge funds, investment banks, traditional banks) generally can be thought of as distinguishing the types of assets and liabilities on their balance sheets.
- Note: lots of stuff can be described in terms of liquidity. Some markets are more liquid than others (how?)

Bank Runs

- Since bank assets (i.e. business loans made by a bank) are often more illiquid than bank liabilities (i.e. checking deposits), it is possible that a bank may not be able to convert their assets into cash quickly enough to satisfy demands.

- A fire sale is a term used to describe a bank selling an illiquid asset more quickly than they would like to, may not receive full value (i.e. rush to sell a Picasso painting quickly).

- If a bank or bank-like institution does not have enough cash (cash on hand + liquidated assets) to satisfy redemption requests for liabilities, bank is declared insolvent.

- Example: your local bank has $10,000,000 in checking deposits. Of this, $1m kept in a vault (cash on hand); the remaining $9m is loaned to businesses (illiquid assets).
  - Normal times: the $1m more than sufficient to satisfy demands from depositors.
  - Bad times: depositors rush in, demand all their deposits back. Bank cannot liquidate assets fast enough (/ at high enough value) to satisfy requests. Bank declared insolvent.

Diamond-Dybvig Model

- **Diamond-Dybvig**: Simplest possible model to capture the idea of a 'bank run.'

- Three period model ($t = 0, 1, 2$) with two agents, depositors (i.e. households) and banks.

- Start by analyzing a version of the model with only one type of agent, depositors, and think about the equilibrium that will naturally emerge with self-interested depositors (autarky) without banks.

- Next, contrast this against the equilibrium that a hypothetical social planner would like to implement by transferring resources across depositors.

- Finally, compare these two benchmark equilibria against the (two) equilibrium outcomes that will emerge with banks. In one equilibrium, banks can help implement the equilibrium chosen by the social planner: banks are good! However, in another equilibrium, a bank run happens, and the resulting equilibrium is even worse than autarky: banks are bad!

Diamond-Dybvig: Depositors

- Continuum of depositors indexed on the unit interval $[0, 1]$.
- Two types of depositors - patient (p) or impatient (i). A depositor doesn't know whether they are impatient or patient until the start of $t = 1$. Let α (exogenous) denote share of impatient households, $1 - \alpha$ share of patient households.
- Patient depositors get utility from consumption in both $t = 1$ and $t = 2$:

$$U(c_1, c_2; p) = u(c_1^p + c_2^p)$$

- Impatient depositors get utility from consumption only in $t = 1$:

$$U(c_1; i) = u(c_1^i)$$

- Assume power utility $u(c) = c^{1-\sigma}/1 - \sigma$ for both types.

Diamond-Dybvig: Investment and Production

- Assume that all depositors have 1 unit available to invest in period 0. Since depositors are indexed on unit interval $[0, 1]$, this implies $\int_0^1 1di = 1$ unit available in aggregate.

- Very stylized production technology: 1 unit of period 0 output can be turned into 1 unit of period 1 output or $R > 1$ (with R exogenous) units of period 2 output.

- Timing of the model for depositors:

  - In $t = 0$, all depositors place their money (1 unit) into (individual) investment accounts.

  - In $t = 1$, each investor first learns their type (patient or impatient) and then decides whether to withdraw their money or not. At this point, the investment has not accumulated any returns (still 1 unit). Withdrawn funds are consumed in the same period. Remaining funds are invested until the final period $t = 2$.

  - In $t = 2$, the remaining money in the investment account experiences a return captured by R, and is withdrawn and consumed.

Diamond-Dybvig: Autarky

- Autarky: What is the equilibrium allocation that would occur if depositors do not interact (no banks or pooled deposits)?

- In period $t = 1$ (the second period), depositors learn whether they are impatient or patient, determine their investment choice and implicitly consumption and savings.

- Impatient households: choose $c_1^i = 1$, $c_2^i = 0$. Impatient types get no utility from consumption in $t = 2$, so withdraw/consume everything in $t = 1$.

- Patient households: choose $c_1^p = 0$, $c_2^p = R$. Patient types get utility from consumption in $t = 1$ and $t = 2$, but based on our functional form for utility + $R > 1$, they do not withdraw anything in period $t = 1$ and instead consume everything in $t = 2$.

- Total utility (across all depositors) in autarky equilibrium:

$$\alpha u(c_1^i) + (1-\alpha)u(c_1^p + c_2^p) = \alpha u(1) + (1-\alpha)u(R)$$

Diamond-Dybvig: Social Planner

- Social planner: What is the amount of consumption that each agent would receive if a social planner wanted to maximize social welfare?

- Social planner can choose fraction of investment x that is kept until period 2:

$$\max_{x} \alpha u(c_1^i) + (1-\alpha)u(c_1^p + c_2^p) \quad \text{s.t.} \quad \alpha c_1^i + (1-\alpha)c_1^p = (1-x)$$
$$(1-\alpha)c_2^p = Rx$$

- Could solve this as usual with Lagrangian multiplier (either with two multipliers, or by consolidating the two constraints into a single constraint so that we have one multiplier).

- Nice shortcut just to simplify the math: recognize that optimal $c_1^p = 0$ (why?). Imposing that and consolidating the constraints:

$$\max_{c_1^i, c_2^p} \alpha u(c_1^i) + (1-\alpha)u(c_2^p) \quad \text{s.t.} \quad \alpha c_1^i + (1-\alpha)\frac{c_2^p}{R} = 1$$

Diamond-Dybvig: Social Planner

- The Lagrangian for the social planner's problem can therefore be written:

$$\mathcal{L}(c_1^i, c_2^p, \lambda) = \alpha u(c_1^i) + (1-\alpha)u(c_2^p) + \lambda\Big[1 - \alpha c_1^i - (1-\alpha)\frac{c_2^p}{R}\Big]$$

- The first-order conditions are $u'(c_1^i) = \lambda$ and $u'(c_2^p) = \lambda/R$.

- Consolidate to eliminate λ and substitute in u' (isoelastic utility):

$$c_2^p = R^\sigma c_1^i$$

- This is one equation and two unknowns (c's). The budget constraint gives us another equation to fully solve.

Diamond-Dybvig: Autarky vs. Planner Allocations

- For convenience, we will superscript consumption allocations that correspond to the planner's solution with *. The planner's solution yields:

$$(c_1^i)^* = \frac{1}{\alpha + (1-\alpha)R^{\sigma-1}} > 1$$
$$(c_2^p)^* = \frac{R}{\alpha R^{1-\sigma} + (1-\alpha)} < R$$

- Clearly this is different from the allocation that would arise under autoarky (with no banks), where $c_1^i = 1$ and $c_2^p = R$. In the planner's solution, patient depositors consume less and impatient depositors consume more relative to the autarky equilibrium.

- Can show that total utility is higher under planner's equilibrium (intuitively, follows from diminishing marginal utility of consumption).

Diamond-Dybvig: Social Planner

- So far, we have seen that with only one type of agent, the equilibrium that emerges (autarky) is sub-optimal, in the sense that total utility (summing across all depositors) is less than what a social planner could achieve.

- Why can the social planner 'do better' than autarky? Intuition: under autarky, patient types have higher total consumption than impatient types (R vs 1). The planner can shift consumption toward the impatient types, raising total utility across all agents (due to diminishing marginal utility).

- Natural question; planner's problem is a useful hypothetical benchmark... but can this allocation ever be realized 'naturally' through a decentralized equilibrium?

- We will add another agent into the model, banks, which can (potentially) lead to the social planner's desired allocation even though agents are acting in their own interest.

Diamond-Dybvig: Banks

- In this model, banks allow allocations to deviate from autarky because the investments of impatient and patient depositors are bundled together - as in the real world.

- The timing of the model is as follows:

(t=0) The bank receives deposits from all depositors in $t = 0$ (total deposits of $\int_0^1 1di = 1$).
(t=1) The bank's assets do not generate a return between $t = 0$ and $t = 1$, so the bank hass \$1 in assets available this period. Depositors have choice to withdraw their deposit and receive $\$r_1$ (exogenous) or to wait.
(t=2) The bank's remaining assets (initial deposits minus withdrawal claims in $t = 1$) realize a gross return of R (exogenous) and are split equally among depositors who did not withdraw in $t = 1$.

- Example: Suppose $r_1 = 1.1$ (10% interest rate), $R = 2$, and the share of depositors who withdraw in the first period is 0.5. Since half the depositors withdraw with $r_1 = 1.1$, the bank has $\$0.45 = \$1 - r_1 \times 0.5$ remaining at the end of $t = 1$. This grows to 0.90 at the start of period 2, which is split equally among the remaining half of depositors.

Diamond-Dybvig: Banks

- Critical: bank assets do not grow between $t = 0$ and $t = 1$; bank only has \$1 in assets when period 1 withdrawals are made.

- If $r_1 = 1$ - that is, no interest is being paid to withdrawing depositors in the first period, they just get their deposit back - then the bank will not run out of money in $t = 1$.

- If $r_1 > 1$, then if a sufficiently high number of depositors withdraw in $t = 1$, then bank can run out of money, and some withdrawal requests cannot be fulfilled (a bank run), and the bank is insolvent.

- Clearly, the impatient depositors will always withdraw in $t = 1$ (they get no utility from consuming in $t = 2$)– but the patient depositors may also withdraw if they expect there not to be any money in the bank, or more generally if the return to withdrawing in $t = 2$ is expected to be lower than the return from withdrawing in $t = 1$.

- How do we capture this story in math?

Diamond-Dybvig: Payoffs to Withdrawal

- Banks service depositors as long as they have funds. When $r_1 > 1$, it is possible that the bank runs out of money before the second period. Need new terms to capture this!

- Impatient depositors always withdraw in period 1. Patient depositors will withdraw in period 2 unless the expected payoff is higher from withdrawing in period 1.

- Let $V_1(f, r_1)$ denote the (dollar) payoff of withdrawing in $t = 1$ with a gross return of r_1, given that a share f depositors are expected to withdraw:

$$V_1(f, r_1) = \begin{cases} r_1 & \text{if} \quad f \cdot r_1 < 1 \\ 0 & \text{if} \quad f \cdot r_1 \geq 1 \end{cases}$$

- Intuition: if $f \cdot r_1 \geq 1$, bank will run out of money in the first period.

- Let $V_2(f, r_1)$ denote the payoff of withdrawing in $t = 2$, given f already withdrawn:

$$V_2(f, r_1) = \max\left\{ \frac{R(1 - r_1 f)}{1 - f}, 0 \right\}$$

Diamond-Dybvig: Non-Bank Run Equilibria

- Two interesting special cases:
  (#1) If $r_1 = 1$, autarky allocation is realized.
  (#2) If $f = \alpha$ and $r_1 = (c_1^i)^*$: social planner's allocation is realized.

- In the first case, without interest being paid for withdrawals in $t = 1$ ($r_1 = 1$), it should be easy to see that $V_2(f, 1) = R > V_1(f, 1) = 1$: patient depositors will always choose to wait to withdraw until $t = 2$.... but in this case, the bank does not improve on the autarky allocation at all.

- In the second case, if $r_1 = (c_1^i)^*$ and $f = \alpha$, then $c_1^i = r_1 = (c_1^i)^*$ and $c_1^p = 0$. If r_1 is set 'just right' and only impatient depositors withdraw, banks *implement the social optimum*!

- So, how does the equilibrium with banks compare against autarky or the social planner's solution? Can be anywhere between, depending on r_1 and f... but these aren't the only possibilities.

Diamond-Dybvig: Bank Runs

- Assume $r_1 > 1$ (not autarky outcome) and patient households **believe** $f \geq 1/r_1$.
- If f is at least as big as $1/r_1$, then $V_2(f, r_1) = 0$: no value to waiting until the last period, even for the patient types.
- In this case, everyone will try to withdraw in the first period. But the bank cannot service everyone's deposits in this case: only a fraction $1/r_1$ of households will get their withdrawals serviced, and the remaining depositors will have 0 consumption – an equilibrium which can be even worse (in total utility terms) than autarky.
- The bank run depends on patient depositors' belief in f - self-fulfilling prophecy.

Diamond-Dybvig: Lessons

- What have we learned from this model?

- Lesson #1: Banks can (potentially) serve as intermediary between types of depositors, achieve the socially-optimal outcome that a centralized planner would like: the "good" equilibrium.

- Lesson #2: The "good" equilibrium is inherently fragile: depends on beliefs of patient depositors. **Expectations matter**. If patient depositors get "spooked", economy can be pushed into bad equilibrium, even worse than autarky (absence of banks).

- Lesson #3: Bank runs can emerge through the natural tension between illiquid assets and liquid liabilities for banks. (Not the only possible cause in the real world - just the only one in this model!).

Diamond-Dybvig: Policy Interventions

- Original tool to prevent bank runs in reality: halts on withdrawals.
- Interbank lending facilities: banks lend to other banks for very short-term loans. Does not help with systemic bank runs.
- Deposit insurance: Government insures deposits up to some amount. Helps reassure patient households, but not large depositors. Doesn't apply to many bank-like institutions (e.g. hedge funds) or businesses with large amounts of cash on hand.
- Lender of last resort: Government / central bank (Fed) offers short-term lending facilities to banks. Very important modern tool. Government provides liquidity.

Diamond-Dybvig: Down the Diamond-Dybvig Rabbit Hole

- The Diamond and Dybvig model we developed is the opening to a very deep rabbit hole in macroeconomics.
- What should optimal government policy look like in an economy that can be prone to bank runs? What are the features of financial crises, what causes them, and how do they differ from 'normal' recessions?
- Diamond-Dybvig framework has been applied to study these questions, but many other frameworks exist (outside this course), loosely outlined in this week's bonus slides.

Bonus Slides

Bonus Slides: Down the Diamond-Dybvig Rabbit Hole

- If we take the Diamond-Dybvig framework seriously, what does 'optimal' government policy look like?

- Important (difficult) reference: Farhi, Golosov, and Tsyvinski (2009): Theory of Liquidity and Regulation of Financial Intermediation.

- More complicated Diamond-Dybvig model, careful attention paid to uncertainty.

- Planner wishes to put a “wedge” between r_1 and the economy's marginal rate of transformation. One feasible way for a government to implement this is to impose a constraint (lower bound) on bank's portfolio share in short-term (more liquid) assets.

- Characteristic of Farhi's work (actual, real-deal genius): Very general, focused on extracting useful, essential content from abstract models.

Bonus Slides: Financial Accelerators

- Lots of ways to think about bank runs, financial crises, etc. that do not build on Diamond and Dybvig.
- Huge literature on business cycle models with financial frictions – models in which credit constraints, liquidity constraints, information asymmetry, and similar kinds of "market imperfections" can generate recessions where financial markets play a key role.
- Useful starting point: Bernanke, Gertler, Gilchrist (1999), "financial accelerator" model. Firms raise money from outside lenders to invest, but information asymmetry (monitoring firms is costly for lenders) means that firms end up paying a premium to borrow from outside lenders. This 'external financing premium' (EFP) depends inversely on firms' net wort: wealthier firms more likely to pay back the loan. If firms' net worth goes down (recession hits), EFP goes up, leading firms to engage in a fire sale of their assets, making other firms' net worth go down.... negative feedback loop amplifies the initial crisis.
- Useful general-purpose model to understand how financial crises can emerge.