Bank Runs, Deposit Insurance, and Liquidity

Douglas W. Diamond
University of Chicago

Philip H. Dybvig
Washington University in Saint Louis

Washington University in Saint Louis
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Motivation

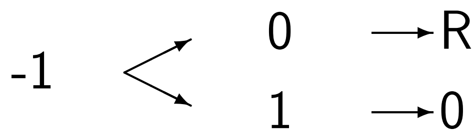
- Originally
  - Model Bank Runs as a Rational Phenomenon of Multiple Equilibrium
- Additional Understanding
  - New Workhorse Model of Liquidity and Banking
  - Deposits as Optimal Contracts for Sharing Risk under Asymmetric Information
- Further thoughts
  - Toy model (not a realistic model)
  - Simplicity (crystal or poem) for clarity and allows generalization

Results

- Bank runs can happen rationally even if bank assets are riskless (and obviously they can still happen with bank assets are risky)
- Banks create liquidity iff runs are possible
- Improved risk sharing can be interpreted as demand for liquidity
- Bank runs can be eliminated by deposit insurance or discount window
- New role for policy in the context of multiple equilibria
  - traditional role: move an equilibrium trading off benefits against distortions
  - role here: eliminate a bad equilibrium but leave the good equilibrium alone

Model: bank assets

Bank asset payoffs in periods 0, 1, and 2, choice made at 1:



Asset illiquidity in technology is for convenience; illiquidity due to information assymmetry (lemons problem) is probably more important. If the liquidation payoff is less than 1 the results are only strengthened.

Model: depositor preferences

Agents maximize $E[u(c_1, c_2; \theta)]$, where

$$U(c_1, c_2; \theta) = \begin{cases} u(c_1) & \text{if Type 1 in state } \theta \\ \rho u(c_1 + c_2) & \text{if Type 2 in state } \theta \end{cases}$$

$$u \text{ is } C^2 \text{ on } \Re_{++} \text{ and } C^0 \text{ on } \Re_+$$

$$u'(0) = \infty, u'(\infty) = 0$$

$$1 \geq \rho > R^{-1}$$

$$(\forall c \geq 1)(-\frac{cu''(c)}{u'(c)} > 1)$$

A fraction t is of type 1 (needs liquidity). The paper analyzes t constant and t random, but I will only talk about t constant. An agent's type is that agent's private information revealed at the start of time 1. There is a continuum of agents and we will finesse the measurability issues in the usual natural way.

Endowments, Competitive and Perfect Information solutions

Endowments: 1 at time 0, 0 each at times 1 and 2

Equilibrium prices without public information: $(1, 1, R^{-1})$, and equilibrium consumption $c_1^1 = 1$, $c_2^1 = c_1^2 = 0$, and $c_2^2 = R$. This equilibrium requires no trade if agents invest themselves: type 1's always interrupt production but Type 2's never do.

Perfect information (types publicly observable at time 1): $c_2^{1*} = c_1^{2*} = 0$ (patient people consume later and impatient people consume earlier), $u'(c_1^{1*}) = \rho R u'(c_2^{2*})$ (marginal rates of substitution in production and consumption are equal), and $tc_1^{1*} + (1-t)c^{2*}/R = 1$ (the resource constraint). Because $\rho R > 1$ and relative risk aversion > 1, it can be shown that $c_1^{1*} > 1$ and $c_2^{2*} < R$. This optimal allocation is in fact incentive-compatible (since $c^{1*} < c^{2*}$), so we should be able to find a mechanism to implement it.

Competitive Model: Choice Problem

Choose nonnegative c_1^1, c_1^2, c_2^1, c_2^2, and I, and choose L_1 and L_2 in $[0, 1]$, to maximize $tu(c_1^1) + (1-t)\rho u(c_1^2 + c_2^2)$
subject to:

$$p_1 c_1^1 + p_2 c_2^1 = p_0(1-I) + p_1 I L_1 + p_2 I(1-L_1)R$$

and

$$p_1 c_1^2 + p_2 c_2^2 = p_0(1-I) + p_1 I L_2 + p_2 I(1-L_2)R$$

Market clearing: $\int I = 1$, $\int (tL_1 + (1-t)L_2)I = \int (tc_1^1 + (1-t)c_1^2)$, and
$R\int (1-(tL_1 + (1-t)L_2))I = \int (tc_2^1 + (1-t)c_2^2)$

Equilibrium: $p_0 = 1$, $p_1 = 1$, $p_2 = R^{-1}$
$c_1^1 = 1$, $c_2^2 = R$, $c_1^2 = c_2^1 = 0$
I many solutions, all have total investment $\int I = 1$
L_1,L_2 many solutions, all have total liquidation $\int (tL_1 + (1-t)L_2)I = t$

same consumption as autarky solution $I = 1$, $L_1 = 1$, $L_2 = 0$

Full Information Optimal Solution

Assume (correctly) a symmetric solution.

Choose nonnegative c_1^1, c_1^2, c_2^1, and c_2^2 to
maximize $tu(c_1^1) + (1-t)\rho u(c_1^2 + c_2^2)$
subject to:
$(tc_1^1 + (1-t)c_1^2) + (tc_2^1 + (1-t)c_2^2)/R = 1$

Solution:
$c_1^2 = c_2^1 = 0$

first-order condition:
$u'(c_1^{1*}) = \rho R u'(c_2^{2*})$

Since $\rho R > 1$, $c_2^{2*} > c_1^{1*}$. Also, $RRA > 1$ implies $c_1^{1*} > 1$ and $c_2^{2*} < R$

Banking Contracts

Per dollar invested, a bank deposit pays r_1 in period 1 and pays off the residual value in the bank (if any) in period 2. Depositors must put all their money in the bank and they cannot trade deposits; this is an important assumption. Depositors in the bank play a simultaneous-move game and decide whether to withdraw based on expectations about how many others will withdraw.

Depositors arrive sequentially, each with a uniform distribution over place in line, and the bank liquidates assets as necessary to pay each depositor until assets are exhausted. Once assets are exhausted, the bank fails and all remaining depositors receive nothing (whether or not they tried to withdraw).

If bank assets are not exhausted, then all depositors who do not withdraw share equally in the assets in the last period. This “mutual bank” assumption avoids the necessity of modelling another agent (the bank owner) and avoids any issues of industrial organization that are not part of what we want to study.

Note: the bank deposit contract satisfies the sequential service constraint.

Bank Depositor Withdrawal Choice Problem

For type 1 agents, withdrawing is a dominant strategy because not withdrawing implies consumption is always 0 but withdrawing implies a positive probability of consuming a positive amount. So we can reasonably assume that type 1 agents always withdraw.[1] Note that the fraction of all agents who withdraw is therefore $f = t + (1-t)f_2 \in [t, 1]$ where $f_2 \in [0, 1]$ is the fraction of type 2 agents who withdraw.

Then, letting W_2 be the withdrawal choice of a type 2 depositor, the type 2 depositor's objective function for $f < 1$ is

$$\max(1-1/(fr_1), 0)\rho u(0) + \min(1/(fr_1), 1)\rho u(W_2 r_1 + (1-W_2)\max(\tfrac{1-fr_1}{1-f}R, 0)).$$

[1] There are examples when elimiation of dominated strategies can lead to strange results, but not so in this model.

Payoffs When $f = 1$

For $f = 1$, the factor $1 - f$ in the denominator indicates there is a problem and in fact fixing the problem is a little subtle. If $r_1 < 1$, the payoff from waiting is infinite because a single infinitessimal agent gets claim to a non-infinitessimal residual in the bank. For $r_1 = 1$, waiting pays off R because not withdrawing leaves just the agent's own claim in the bank, and the agent will optimally choose not to withdraw. This observation can be used to show that $r_1 = 1$ leads to the autarky solution. The remaining case, when $r_1 > 1$, is the normal case and the most interesting. In this case, $f = 1$ exhausts the bank's assets even if the agent under consideration does not withdraw, and the payoff for $f = 1$ and $r_1 > 1$ is therefore

$$\max(1 - 1/(fr_1), 0)\rho u(0) + \min(1/(fr_1), 1)\rho u(W_2 r_1).$$

Banking Equilibrium

For $1 < r_1 \leq c_1^{1*}$, there are two types of pure strategy equilibria:

run: $f = W_1 = W_2 = 1$

Impatient depositors always withdraw in period 1 because consumption in period 2 is worthless to them. Patient depositors will withdraw if they think they will get more money now than later. If $r_1 > 1$, then the bank will exhaust its money at time 1 if everyone withdraws, so everyone withdrawing at time 1 is an equilibrium. This is a bank run, which is purely rational, not a psychological phenomenon. If $r_1 = 1$, there will be no bank run, but neither will there be any improvement over autarky.

no run: $W_1 = 1$, $W_2 = 0$, and $f = t$
(First-best if $r_1 = c_1^{1*}$, which implies $\frac{1-fr_1}{1-f}R = c_2^{2*}$)

This is a good equilibrium in which agents only withdraw when impatient, provided r_1 is no larger than the amount that is left over if only impatient agents withdraw.

Technical Comments

Measure theoretic issue: if we draw uncountably many random variables indexed by the unit interval independently, the realized function is not measurable, so the population average does not exist. This problem was emphasized by Ken Judd. Solutions include using the limit of a sequence economy (messy). The usually practice of taking the population mean equal to the mean of the distribution can be justified by Loeb measure in a hyperfinite economy (Bob Anderson) or the measure-theoretic solution of Ed Green (unpublished article on his web site).

We want to assume $u(0)$ finite and $(\forall c \in [1,R]) - cu''(c)/u'(c) > 1$. This is different from the paper, which implicitly assumes $u(0)$ finite and explicitly assumes $(\forall c \in \Re) - cu''(c)/u'(c) > 1$. Unfortunately the two are inconsistent.)-:

Role of Government Policy

Usually, government policy (e.g. optimal taxation) is modelled as something (e.g. introducing transfers) that moves the equilibrium allocation in a good direction, usually reflecting a trade-off between a desireable outcome (transfer on income to poor people) at the expense of some distortion (because of taxes, the marginal rates of substitution in production and consumption are no longer equal, so that production is not efficient).

Preventing runs in banks is different. We want a governmental policy (or private sector fix) that will eliminate the bad equilibrium without affecting the good equilibrium.

Deposit Insurance, Suspension of Convertibility, and the Discount Window

To eliminate runs, we need to reassure patient depositors that there will be enough money available to pay them off in the period 2. One way is through deposit insurance, which will pay off the shortfall from the promise in the second period. Given that deposit insurance is in place, the patient agents have no incentive to withdraw in period 1 and there is no run equilibrium.

Suspension of convertibility (can be very costly if t random). The idea is to stop paying if too many depositors come to the bank in period 1.

Discount window (may not be credible for reasons outside the model)

Timing issues, sequential service, timing of credit injection

Deposit Insurance

Let's focus on $r_1 = c_1^{1^*}$. It would be nice if we could design a policy that eliminates the run equilibrium without disrupting the optimal no-run equilibrium. In fact, a guarantee to people that wait that they will get money back when they wait (perhaps backed by seignorage and/or taxation authority) will do so. Let the guarantee be $G \in (r_1, R]$. A guarantee in period 2 does not affect the incentives of a type 1 agent. For a type 2 agent, the payoff if $f < 1$ becomes

$$\max(1-1/(fr_1), 0)\rho u(0) + \min(1/(fr_1), 1)\rho u(W_2 r_1 + (1-W_2)\max(\tfrac{1-fr_1}{1-f}R, G)),$$

which is decreasing in W_2. Similarly, if $f = 1$ the payoff is

$$\max(1 - 1/(fr_1), 0)\rho u(0) + \min(1/(fr_1), 1)\rho u(W_2 r_1 + (1 - W_2)G),$$

which is also decreasing in W_2.

Discount Window, Practical Considerations

Use of riskless borrowing at the discount window could also prevent runs, but the policy for using the discount window would have to be designed carefully. If unlimited borrowing is available at a low rate, there is an arbitrage and the discount window could be used to finance investment. However, if the rate is high it will not help the bank any (assuming the bank will repay the borrowing). So, the central bank will probably need to use discretion in deciding there is a run before lending, but in this case maybe it is not credible that the discount window will necessarily be available when the bank needs it. For example, the central bank might decide the bank is unsound and refuse access to the discount window.

Note that deposit insurance costs the guarantor nothing in our model, but in practice risky assets would make deposit insurance costly so that the guarantor would have to have some type of incentive scheme and monitoring to guard against risky assets.

Suspension of Convertibility, Sequential Service, Random t

Suspension of convertibility can stop a run (for example, if only the first t depositors are paid off in period 1 and the rest have to wait), but such a rigid policy can do a lot of damage if t is random.

With sequential service and random t, in general it is optimal to offer a contract that pays more to early withdrawers. If it were possible, it would be nice to wait and see how many total withdrawers arrive before deciding how much money to give everyone, but we think that is impractical.

Review of ideas

- Bank runs can be generated by rational agent behavior, even when assets are riskless.
- Bank deposits can improve on the competitive outcome because they provide liquidity.
- Providing liquidity improves risk sharing, but makes runs possible.
- The basic approach can be used to model many issues in banking.
- The basic approach can also be used to model liquidity in many contexts.

more on policy:
Diamond, Douglas W., and Philip H. Dybvig, 1986, "Banking Theory, Deposit Insurance, and Bank Regulation," *Journal of Business* **59**, 55–68

some recent work:
http://phildybvig.com/somepapers.html