Bank Runs, Deposit Insurance, and Liquidity

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This paper shows that bank deposit contracts can provide allocations superior to those of exchange markets, offering an explanation of how banks subject to runs can attract deposits. Investors face privately observed risks which lead to a demand for liquidity. Traditional demand deposit contracts which provide liquidity have multiple equilibria, one of which is a bank run. Bank runs in the model cause real economic damage, rather than simply reflecting other problems. Contracts which can prevent runs are studied, and the analysis shows that there are circumstances when government provision of deposit insurance can produce superior contracts.

I. Introduction

Bank runs are a common feature of the extreme crises that have played a prominent role in monetary history. During a bank run, depositors rush to withdraw their deposits because they expect the bank to fail. In fact, the sudden withdrawals can force the bank to liquidate many of its assets at a loss and to fail. In a panic with many bank failures, there is a disruption of the monetary system and a reduction in production.

Institutions in place since the Great Depression have successfully prevented bank runs in the United States since the 1930s. Nonethe-

We are grateful for helpful comments from Milt Harris, Burt Malkiel, Mike Mussa, Art Raviv, and seminar participants at Chicago, Northwestern, Stanford, and Yale.

[*Journal of Political Economy*, 1983, vol. 91, no. 3]
 0022-3808/83/9103-0004$01.50

less, current deregulation and the dire financial condition of savings and loans make bank runs and institutions to prevent them a current policy issue, as shown by recent aborted runs.[1] (Internationally, Eurodollar deposits tend to be uninsured and are therefore subject to runs, and this is true in the United States as well for deposits above the insured amount.) It is good that deregulation will leave banking more competitive, but we must ensure that banks will not be left vulnerable to runs.

Through careful description and analysis, Friedman and Schwartz (1963) have provided substantial insight into the properties of past bank runs in the United States. Existing theoretical analysis has neglected to explain why bank contracts are less stable than other types of financial contracts or to investigate the strategic decisions that depositors face. The model we present has an explicit economic role for banks to perform: the transformation of illiquid assets into liquid liabilities. The analyses of Patinkin (1965, chap. 5), Tobin (1965), and Niehans (1978) provide insights into characterizing the liquidity of assets. This paper gives the first explicit analysis of the demand for liquidity and the "transformation" service provided by banks. Uninsured demand deposit contracts are able to provide liquidity but leave banks vulnerable to runs. This vulnerability occurs because there are multiple equilibria with differing levels of confidence.

Our model demonstrates three important points. First, banks issuing demand deposits can improve on a competitive market by providing better risk sharing among people who need to consume at different random times. Second, the demand deposit contract providing this improvement has an undesirable equilibrium (a bank run) in which all depositors panic and withdraw immediately, including even those who would prefer to leave their deposits in if they were not concerned about the bank failing. Third, bank runs cause real economic problems because even "healthy" banks can fail, causing the recall of loans and the termination of productive investment. In addition, our model provides a suitable framework for analysis of the devices traditionally used to stop or prevent bank runs, namely, suspension of convertibility and demand deposit insurance (which works similarly to a central bank serving as "lender of last resort").

The illiquidity of assets enters our model through the economy's riskless production activity. The technology provides low levels of output per unit of input if operated for a single period but high levels

[1] The aborted runs on Hartford Federal Savings and Loan (Hartford, Conn., February 1982) and on Abilene National Bank (Abilene, Texas, July 1982) are two recent examples. The large amounts of uninsured deposits in the recently failed Penn Square Bank (Oklahoma City, July 1982) and its repercussions are another symptom of banks' current problems.

of output if operated for two periods. The analysis would be the same if the asset were illiquid because of selling costs: one receives a low return if unexpectedly forced to "liquidate" early. In fact, this illiquidity is a property of the financial assets in the economy in our model, even though they are traded in competitive markets with no transaction costs. Agents will be concerned about the cost of being forced into early liquidation of these assets and will write contracts which reflect this cost. Investors face private risks which are not directly insurable because they are not publicly verifiable. Under optimal risk sharing, this private risk implies that agents have different time patterns of return in different private information states and that agents want to allocate wealth unequally across private information states. Because only the agent ever observes the private information state, it is impossible to write insurance contracts in which the payoff depends directly on private information, without an explicit mechanism for information flow. Therefore, simple competitive markets cannot provide this liquidity insurance.

Banks are able to transform illiquid assets by offering liabilities with a different, smoother pattern of returns over time than the illiquid assets offer. These contracts have multiple equilibria. If confidence is maintained, there can be efficient risk sharing, because in that equilibrium a withdrawal will indicate that a depositor should withdraw under optimal risk sharing. If agents panic, there is a bank run and incentives are distorted. In that equilibrium, everyone rushes in to withdraw their deposits before the bank gives out all of its assets. The bank must liquidate all its assets, even if not all depositors withdraw, because liquidated assets are sold at a loss.

Illiquidity of assets provides the rationale both for the existence of banks and for their vulnerability to runs. An important property of our model of banks and bank runs is that runs are costly and reduce social welfare by interrupting production (when loans are called) and by destroying optimal risk sharing among depositors. Runs in many banks would cause economy-wide economic problems. This is consistent with the Friedman and Schwartz (1963) observation of large costs imposed on the U.S. economy by the bank runs in the 1930s, although they attribute the real damage from bank runs as occurring through the money supply.

Another contrast with our view of how bank runs do economic damage is discussed by Fisher (1911, p. 64).[2] In this view, a run occurs because the bank's assets, which are liquid but risky, no longer cover the nominally fixed liability (demand deposits), so depositors withdraw quickly to cut their losses. The real losses are indirect, through

[2] Bryant (1980) also takes this view.

the loss of collateral caused by falling prices. In contrast, a bank run in our model is caused by a shift in expectations, which could depend on almost anything, consistent with the apparently irrational observed behavior of people running on banks.

We analyze bank contracts that can prevent runs and examine their optimality. We show that there is a feasible contract that allows banks both to prevent runs and to provide optimal risk sharing by converting illiquid assets. The contract corresponds to suspension of convertibility of deposits (to currency), a weapon banks have historically used against runs. Under other conditions, the best contract that banks can offer (roughly, the suspension-of-convertibility contract) does not achieve optimal risk sharing. However, in this more general case there is a contract which achieves the unconstrained optimum when government deposit insurance is available. Deposit insurance is shown to be able to rule out runs without reducing the ability of banks to transform assets. What is crucial is that deposit insurance frees the asset liquidation policy from strict dependence on the volume of withdrawals. Other institutions such as the discount window ("lender of last resort") may serve a similar function; however, we do not model this here. The taxation authority of the government makes it a natural provider of the insurance, although there may be a competitive fringe of private insurance.

Government deposit insurance can improve on the best allocations that private markets provide. Most of the existing literature on deposit insurance assumes away any real service from deposit insurance, concentrating instead on the question of pricing the insurance, taking as given the likelihood of failure (see, e.g., Merton 1977, 1978; Kareken and Wallace 1978; Dothan and Williams 1980).

Our results have far-reaching policy implications, because they imply that the real damage from bank runs is primarily from the direct damage occurring when recalling loans interrupts production. This implies that much of the economic damage in the Great Depression was *caused* directly by bank runs. A study by Bernanke (in press) supports our thesis, as it shows that bank runs give a better predictor of economic distress than money supply.

The paper proceeds as follows. In the next section, we analyze a simple economy which shows that banks can improve the risk sharing of simple competitive markets by transforming illiquid assets. We show that such banks are always vulnerable to runs. In Section III, we analyze the optimal bank contracts that prevent runs. In Section IV, we analyze bank contracts, dropping the previous assumption that the volume of withdrawals is deterministic. Deposit insurance is analyzed in Section V. Section VI concludes the paper.

II. The Bank's Role in Providing Liquidity

Banks have issued demand deposits throughout their history, and economists have long had the intuition that demand deposits are a vehicle through which banks fulfill their role of turning illiquid assets into liquid assets. In this role, banks can be viewed as providing insurance that allows agents to consume when they need to most. Our simple model shows that asymmetric information lies at the root of liquidity demand, a point not explicitly noted in the previous literature.

The model has three periods ($T = 0, 1, 2$) and a single homogeneous good. The productive technology yields $R > 1$ units of output in period 2 for each unit of input in period 0. If production is interrupted in period 1, the salvage value is just the initial investment. Therefore, the productive technology is represented by

$$\begin{array}{ccc} T = 0 & T = 1 & T = 2 \\ -1 & \begin{cases} 0 \\ 1 \end{cases} & \begin{matrix} R \\ 0, \end{matrix} \end{array}$$

where the choice between $(0, R)$ and $(1, 0)$ is made in period 1. (Of course, constant returns to scale implies that a fraction can be done in each option.)

One interpretation of the technology is that long-term capital investments are somewhat irreversible, which appears to be a reasonable characterization. The results would be reinforced (or can be alternatively motivated) by any type of transaction cost associated with selling a bank's assets before maturity. See Diamond (1980) for a model of the costly monitoring of loan contracts by banks, which implies such a cost.

All consumers are identical as of period 0. Each faces a privately observed, uninsurable risk of being of type 1 or of type 2. In period 1, each agent (consumer) learns his type. Type 1 agents care only about consumption in period 1 and type 2 agents care only about consumption in period 2. In addition, all agents can privately store (or "hoard") consumption goods at no cost. This storage is not publicly observable. No one would store between $T = 0$ and $T = 1$, because the productive technology does at least as well (and better if held until $T = 2$). If an agent of type 2 obtains consumption goods at $T = 1$, he will store them until $T = 2$ to consume them. Let c_T represent goods "received" (to store or consume) by an agent at period T. The privately observed consumption at $T = 2$ of a type 2 agent is then what he stores from $T = 1$ plus what he obtains at $T = 2$, or $c_1 + c_2$. In terms of this publicly observed variable c_T the discussion above implies

that each agent has a state-dependent utility function (with the state private information), which we assume has the form

$$U(c_1, c_2; \Theta) = \begin{cases} u(c_1) & \text{if } j \text{ is of type 1 in state } \Theta \\ \rho u(c_1 + c_2) & \text{if } j \text{ is of type 2 in state } \Theta, \end{cases}$$

where $1 \geq \rho > R^{-1}$ and $u: R_{++} \to R$ is twice continuously differentiable, increasing, strictly concave, and satisfies Inada conditions $u'(0) = \infty$ and $u'(\infty) = 0$. Also, we assume that the relative risk-aversion coefficient $-cu''(c)/u'(c) > 1$ everywhere. Agents maximize expected utility, $E[u(c_1, c_2; \Theta)]$, conditional on their information (if any).

A fraction $t \in (0, 1)$ of the continuum of agents are of type 1 and, conditional on t, each agent has an equal and independent chance of being of type 1. Later sections will allow t to be random (in which case, at period 1, consumers know their own type but not t), but for now we take t to be constant.

To complete the model, we give each consumer an endowment of 1 unit in period 0 (and none at other times). We consider first the competitive solution where agents hold the assets directly, and in each period there is a competitive market in claims on future goods. It is easy to show that because of the constant returns technology, prices are determined: the period 0 price of period 1 consumption is 1, and the period 0 and 1 prices of period 2 consumption are R^{-1}. This is because agents can write only uncontingent contracts as there is no public information on which to condition. Contracting in period $T = 0$, all agents (who are then identical) will establish the same trades and each will invest his endowment in the production technology. Given this identical position of each agent at $T = 0$, there will be trade in claims on goods for consumption at $T = 1$ and at $T = 2$. Each has access to the same technology and each can choose any positive linear combination of $c_1 = 1$ and $c_2 = R$. Each individual's production set is proportional to the aggregate set, and for there to be positive production of both c_1 and c_2, the period $T = 1$ price of c_2 must be R^{-1}. Given these prices, there is never any trade, and agents can do no better or worse than if they produced only for their own consumption. Letting c_k^i be consumption in period k of an agent who is of type i, the agents choose $c_1^1 = 1$, $c_2^1 = c_1^2 = 0$, and $c_2^2 = R$, since type 1's always interrupt production but type 2's never do.

By comparison, if types were *publicly* observable as of period 1, it would be possible to write optimal insurance contracts that give the ex ante (as of period 0) optimal sharing of output between type 1 and type 2 agents. The optimal consumption $\{c_k^{i*}\}$ satisfies

$$c_1^{2*} = c_2^{1*} = 0 \tag{1a}$$

(those who can, delay consumption),

$$u'(c_1^{1*}) = \rho R u'(c_2^{2*}) \tag{1b}$$

(marginal utility in line with marginal productivity), and

$$tc_1^{1*} + [(1 - t)c_2^{2*}/R] = 1 \tag{1c}$$

(the resource constraint).

By assumption, $\rho R > 1$, and since relative risk aversion always exceeds unity, equation (1) implies that the optimal consumption levels satisfy $c_1^{1*} > 1$ and $c_2^{2*} < R$.[3] Therefore, there is room for improvement on the competitive outcome ($c_1^1 = 1$ and $c_2^2 = R$). Also, note that $c_2^{2*} > c_1^{1*}$ by equation (1b), since $\rho R > 1$.

The optimal insurance contract just described would allow agents to insure against the unlucky outcome of being a type 1 agent. This contract is not available in the simple contingent-claims market. Also, the lack of observability of agents' types rules out a complete market of Arrow-Debreu state-contingent claims, because this market would require claims that depend on the nonverifiable private information. Fortunately it is potentially possible to achieve the optimal insurance contract, since the optimal contract satisfies the self-selection constraints.[4] We argue that banks can provide this insurance: by provid-

[3] The proof of this is as follows:

$$\begin{aligned}
\rho R u'(R) &< R u'(R) \\
&= 1 \cdot u'(1) + \int_{\gamma=1}^{R} \frac{\partial}{\partial \gamma} [\gamma u'(\gamma)] d\gamma \\
&= u'(1) + \int_{\gamma=1}^{R} [u'(\gamma) + u''(\gamma)] d\gamma \\
&< u'(1),
\end{aligned}$$

as $u' > 0$ and $(\forall\, \gamma)\ -u''(\gamma)\gamma/u'(\gamma) > 1$. Because $u'(\cdot)$ is decreasing and the resource constraint (1c) trades off c_1^{1*} against c_2^{2*}, the solution to (1) must have $c_1^{1*} > 1$ and $c_2^{2*} < R$.

[4] The self-selection constraints state that no agent envies the treatment by the market of other indistinguishable agents. In our model, agents' utilities depend on only their consumption vectors across time and all have identical endowments. Therefore, the self-selection constraints are satisfied if no agent envies the consumption bundle of any other agent. This can be shown for optimal risk sharing using the properties described after (1). Because $c_1^{1*} > 1$ and $c_1^{2*} = 0$, type 1 agents do not envy type 2 agents. Furthermore, because $c_1^{2*} + c_2^{2*} = c_2^{2*} > c_1^{1*} = c_1^{1*} + c_2^{1*}$, type 2 agents do not envy type 1 agents. Because the optimal contract satisfies the self-selection constraints, there is necessarily a contract structure which implements it as a Nash equilibrium—the ordinary demand deposit is a contract which will work. However, the optimal allocation is not the unique Nash equilibrium under the ordinary demand deposit contract. Another inferior equilibrium is what we identify as a bank run. Our model gives a real-world example of a situation in which the distinction between implementation as a Nash equilibrium and implementation as a *unique* Nash equilibrium is crucial (see also Dybvig and Spatt, in press, and Dybvig and Jaynes 1980).

ing liquidity, banks guarantee a reasonable return when the investor cashes in before maturity, as is required for optimal risk sharing. To illustrate how banks provide this insurance, we first examine the traditional demand deposit contract, which is of particular interest because of its ubiquitous use by banks. Studying the demand deposit contract in our framework also indicates why banks are susceptible to runs.

In our model, the demand deposit contract gives each agent withdrawing in period 1 a fixed claim of r_1 per unit deposited at time 0. Withdrawal tenders are served sequentially in random order until the bank runs out of assets. This approach allows us to capture the flavor of continuous time (in which depositors deposit and withdraw at different random times) in a discrete model. Note that the demand deposit contract satisfies a *sequential service constraint,* which specifies that a bank's payoff to any agent can depend only on the agent's place in line and not on future information about agents behind him in line.

We are assuming throughout this paper that the bank is mutually owned (a "mutual") and liquidated in period 2, so that agents not withdrawing in period 1 get a pro rata share of the bank's assets in period 2. Let V_1 be the period 1 payoff per unit deposit withdrawn which depends on one's place in line at $T = 1$, and let V_2 be the period 2 payoff per unit deposit not withdrawn at $T = 2$, which depends on total withdrawals at $T = 1$. These are given by

$$V_1(f_j, r_1) = \begin{cases} r_1 & \text{if } f_j < r_1^{-1} \\ 0 & \text{if } f_j \geq r_1^{-1} \end{cases} \tag{2}$$

and

$$V_2(f, r_1) = \max \{R(1 - r_1 f)/(1 - f), 0\}, \tag{3}$$

where f_j is the number of withdrawers' deposits serviced before agent j as a fraction of total demand deposits; f is the total number of demand deposits withdrawn. Let w_j be the fraction of agent j's deposits that he attempts to withdraw at $T = 1$. The consumption from deposit proceeds, per unit of deposit of a type 1 agent, is thus given by $w_j V_1(f_j, r_1)$, while the total consumption, from deposit proceeds, per unit of deposit of a type 2 agent is given by $w_j V_1(f_j, r_1) + (1 - w_j)V_2(f, r_1)$.

Equilibrium Decisions

The demand deposit contract can achieve the full-information optimal risk sharing as an equilibrium. (By equilibrium, we will always

refer to pure strategy Nash equilibrium[5]—and for now we will assume all agents are required to deposit initially.) This occurs when $r_1 = c_1^{1*}$, that is, when the fixed payment per dollar of deposits withdrawn at $T = 1$ is equal to the optimal consumption of a type 1 agent given full information. If this contract is in place, it is an equilibrium for type 1 agents to withdraw at $T = 1$ and for type 2 agents to wait, provided this is what is anticipated. This "good" equilibrium achieves optimal risk sharing.[6]

Another equilibrium (a bank run) has all agents panicking and trying to withdraw their deposits at $T = 1$: if this is anticipated, all agents will prefer to withdraw at $T = 1$. This is because the face value of deposits is larger than the liquidation value of the bank's assets.

It is precisely the "transformation" of illiquid assets into liquid assets that is responsible both for the liquidity service provided by banks and for their susceptibility to runs. For all $r_1 > 1$, runs are an equilibrium.[7] If $r_1 = 1$, a bank would not be susceptible to runs because $V_1(f_j, 1) < V_2(f, 1)$ for all values of $0 \leq f_j \leq f$; but if $r_1 = 1$, the bank simply mimics direct holding of the assets and is therefore no improvement on simple competitive claims markets. A demand deposit contract which is not subject to runs provides no liquidity services.

The bank run equilibrium provides allocations that are worse for all agents than they would have obtained without the bank (trading in the competitive claims market). In the bank run equilibrium, everyone receives a risky return that has a mean one. Holding assets directly provides a riskless return that is at least one (and equal to $R > 1$ if an agent becomes a type 2). Bank runs ruin the risk sharing between agents and take a toll on the efficiency of production because all production is interrupted at $T = 1$ when it is optimal for some to continue until $T = 2$.

If we take the position that outcomes must match anticipations, the inferiority of bank runs seems to rule out observed runs, since no one would deposit anticipating a run. However, agents will choose to deposit at least some of their wealth in the bank even if they anticipate a positive probability of a run, provided that the probability is small enough, because the good equilibrium dominates holding assets di-

[5] This assumption rules out a mixed strategy equilibrium which is not economically meaningful.

[6] To verify this, substitute $f = t$ and $r_1 = c_1^{1*}$ into (2) and (3), noting that this leads to $V_1(\cdot) = c_1^{1*}$ and $V_2(\cdot) = c_2^{2*}$. Because $c_2^{2*} > c_1^{1*}$, all type 2's prefer to wait until time 2 while type 1's withdraw at 1, implying that $f = t$ is an equilibrium.

[7] The value $r_1 = 1$ is the value which rules out runs and mimics the competitive market because that is the per unit $T = 1$ liquidating value of the technology. If that liquidating value were $\Theta < 1$, then $r_1 = \Theta$ would have this property. It has nothing directly to do with the zero rate of interest on deposits.

rectly. This could happen if the selection between the bank run equilibrium and the good equilibrium depended on some commonly observed random variable in the economy. This could be a bad earnings report, a commonly observed run at some other bank, a negative government forecast, or even sunspots.[8] It need not be anything fundamental about the bank's condition. The problem is that once they have deposited, anything that causes them to anticipate a run will lead to a run. This implies that banks with pure demand deposit contracts will be very concerned about maintaining confidence because they realize that the good equilibrium is very fragile.

The pure demand deposit contract is feasible, and we have seen that it can attract deposits even if the perceived probability of a run is positive. This explains why the contract has actually been used by banks in spite of the danger of runs. Next, we examine a closely related contract that can help to eliminate the problem of runs.

III. Improving on Demand Deposits: Suspension of Convertibility

The pure demand deposit contract has a good equilibrium that achieves the full-information optimum when t is not stochastic. However, in its bank run equilibrium, it is worse than direct ownership of assets. It is illuminating to begin the analysis of optimal bank contracts by demonstrating that there is a simple variation on the demand deposit contract which gives banks a defense against runs: suspension of allowing withdrawal of deposits, referred to as suspension of convertibility (of deposits to cash). Our results are consistent with the claim by Friedman and Schwartz (1963) that the newly organized Federal Reserve Board may have made runs in the 1930s worse by preventing banks from suspending convertibility: the total week-long banking "holiday" that followed was more severe than any of the previous suspensions.

If banks can suspend convertibility when withdrawals are too numerous at $T = 1$, anticipation of this policy prevents runs by removing the incentive of type 2 agents to withdraw early. The following contract is identical to the pure demand deposit contract described in (2) and (3), except that it states that any agent will receive nothing at $T = 1$ if he attempts to withdraw at $T = 1$ after a fraction $\hat{f} < r_1^{-1}$ of all deposits have already been withdrawn—note that we

[8] Analysis of this point in a general setting is given in Azariadis (1980) and Cass and Shell (1983).

redefine $V_1(\cdot)$ and $V_2(\cdot)$,

$$V_1(f_j, r_1) = \begin{cases} r_1 & \text{if } f_j \leq \hat{f} \\ 0 & \text{if } f_j > \hat{f} \end{cases}$$

$$V_2(f, r_1) = \max\left\{\frac{(1 - fr_1)R}{1 - f}, \frac{(1 - \hat{f}r_1)R}{1 - \hat{f}}\right\},$$

where the expression for V_2 assumes that $1 - \hat{f}r_1 > 0$.

Convertibility is suspended when $f_j = \hat{f}$, and then no one else "in line" is allowed to withdraw at $T = 1$. To demonstrate that this contract can achieve the optimal allocation, let $r_1 = c_1^{1*}$ and choose any $\hat{f} \in \{t, [(R - r_1)/r_1(R - 1)]\}$. Given this contract, no type 2 agent will withdraw at $T = 1$ because no matter what he anticipates about others' withdrawals, he receives higher proceeds by waiting until $T = 2$ to withdraw; that is, for all f and $f_j \leq f$, $V_2(\cdot) > V_1(\cdot)$. All of the type 1's will withdraw everything at period 1 because period 2 consumption is worthless to them. Therefore, there is a unique Nash equilibrium which has $f = t$. In fact, this is a dominant strategy equilibrium, because each agent will choose his equilibrium action even if he anticipates that other agents will choose nonequilibrium or even irrational actions. This makes this contract very "stable." This equilibrium is essentially the good demand deposit equilibrium that achieves optimal risk sharing.

A policy of suspension of convertibility at $\hat{f}$ guarantees that it will never be profitable to participate in a bank run because the liquidation of the bank's assets is terminated while type 2's still have an incentive not to withdraw. This contract works perfectly only in the case where the normal volume of withdrawals, t, is known and not stochastic. The more general case, where t can vary, is analyzed next.

IV. Optimal Contracts with Stochastic Withdrawals

The suspension of convertibility contract achieves optimal risk sharing when t is known ex ante because suspension never occurs in equilibrium and the bank can follow the optimal asset liquidation policy. This is possible because the bank knows exactly how many withdrawals will occur when confidence is maintained. We now allow the fraction of type 1's to be an unobserved random variable, $\tilde{t}$. We consider a general class of bank contracts where payments to those who withdraw at $T = 1$ are any function of f_j and payments to those who withdraw at $T = 2$ are any function of f. Analyzing this general class will show the shortcomings of suspension of convertibility.

The full-information optimal risk sharing is the same as before,

except that in equation (1) the actual realization of $\tilde{t} = t$ is used in place of the fixed t. As no single agent has information crucial to learning the value of t, the arguments of footnote 3 still show that optimal risk sharing is consistent with self-selection, so there must be some mechanism which has optimal risk sharing as a Nash equilibrium. We now explore whether banks (which are subject to the constraint of sequential service) can do this too.

From equation (1) we obtain full-information optimal consumption levels, given the realization of $\tilde{t} = t$, of $c_1^{1*}(t)$ and $c_2^{2*}(t)$. Recall that $c_2^{1*}(t) = c_1^{2*}(t) = 0$. At the optimum, consumption is equal for all agents of a given type and depends on the realization of t. This implies a unique optimal asset liquidation policy given $\tilde{t} = t$. This turns out to imply that uninsured bank deposit contracts cannot achieve optimal risk sharing.

PROPOSITION 1: Bank contracts (which must obey the sequential service constraint) cannot achieve optimal risk sharing when t is stochastic and has a nondegenerate distribution.

Proposition 1 holds for all equilibria of uninsured bank contracts of the general form $V_1(f_j)$ and $V_2(f)$, where these can be any function. It obviously remains true that uninsured pure demand deposit contracts are subject to runs. Any run equilibrium does not achieve optimal risk sharing, because both types of agents receive the same consumption. Consider the good equilibrium for any feasible contract. We prove that no bank contract can attain the full-information optimal risk sharing. The proof is straightforward, a two-part proof by contradiction. Recall that the "place in line" f_j is uniformly distributed over $[0, t]$ if only type 1 agents withdraw at $T = 1$. First, suppose that the payments to those who withdraw at $T = 1$ is a nonconstant function of f_j over feasible values of t: for two possible values of $\tilde{t}$, t_1 and t_2, the value of a period 1 withdrawal varies, that is, $V_1(t_1) \neq V_1(t_2)$. This immediately implies that there is a positive probability of different consumption levels by two type 1 agents who will withdraw at $T = 1$, and this contradicts an unconstrained optimum. Second, assume the contrary: that for all possible realizations of $\tilde{t} = t$, $V_1(f_j)$ is constant for all $f_j \in [0, t]$. This implies that $c_1^1(t)$ is a constant independent of the realization of $\tilde{t}$, while the budget constraint, equation (1c), shows that $c_2^2(t)$ will vary with t (unless $r_1 = 1$, which is itself inconsistent with optimal risk sharing). Constant $c_1^1(t)$ and varying $c_2^2(t)$ contradict optimal risk sharing, equation (1b). Thus, optimal risk sharing is inconsistent with sequential service.

Proposition 1 implies that no bank contract, including suspension convertibility, can achieve the full-information optimum. Nonetheless, suspension can generally improve on the uninsured demand deposit contract by preventing runs. The main problem occurs when

convertibility is suspended in equilibrium, that is, when the point $\hat{f}$ where suspension occurs is less than the largest possible realization of $\tilde{t}$. In that case, some type 1 agents cannot withdraw, which is inefficient ex post. This can be desirable ex ante, however, because the threat of suspension prevents runs and allows a relatively high value of r_1. This result is consistent with contemporary views about suspension in the United States in the period before deposit insurance. Although suspensions served to short-circuit runs, they were "regarded as anything but a satisfactory solution by those who experienced them, which is why they produced so much strong pressure for monetary and banking reform" (Friedman and Schwartz 1963, p. 329). The most important reform that followed was federal deposit insurance. Its impact is analyzed in Section V.

V. Government Deposit Insurance

Deposit insurance provided by the government allows bank contracts that can dominate the best that can be offered without insurance and never do worse. We need to introduce deposit insurance into the analysis in a way that keeps the model closed and assures that no aggregate resource constraints are violated. Deposit insurance guarantees that the promised return will be paid to all who withdraw. If this is a guarantee of a real value, the amount that can be guaranteed is constrained: the government must impose real taxes to honor a deposit guarantee. If the deposit guarantee is nominal, the tax is the (inflation) tax on nominal assets caused by money creation. (Such taxation occurs even if no inflation results; in any case the price level is higher than it would have been otherwise, so some nominally denominated wealth is appropriated.) Because a private insurance company is constrained by its reserves in the scale of unconditional guarantees which it can offer, we argue that deposit insurance probably ought to be governmental for this reason. Of course, the deposit guarantee could be made by a private organization with some authority to tax or create money to pay deposit insurance claims, although we would usually think of such an organization as being a branch of government. However, there can be a small competitive fringe of commercially insured deposits, limited by the amount of private collateral.

The government is assumed to be able to levy any tax that charges every agent in the economy the same amount. In particular, it can tax those agents who withdrew "early" in period $T = 1$, namely, those with low values of f_j. How much tax must be raised depends on how many deposits are withdrawn at $T = 1$ and what amount r_1 was promised to them. For example, if every deposit of one dollar were

withdrawn at $T = 1$ (implying $f = 1$) and $r_1 = 2$ were promised, a tax of at least one per capita would need to be raised because totally liquidating the bank's assets will raise at most one per capita at $T = 1$. As the government can impose a tax on an agent *after* he or she has withdrawn, the government can base its tax on f, the realized total value of $T = 1$ withdrawals. This is in marked contrast to a bank, which must provide sequential service and cannot reduce the amount of a withdrawal after it has been made. This asymmetry allows a potential benefit from government intervention. The realistic sequential-service constraint represents some services that a bank provides but which we do not explicitly model. With deposit insurance we will see that imposing this constraint does not reduce social welfare.

Agents are concerned with the after-tax value of the proceeds from their withdrawals because that is the amount that they can consume. A very strong result (which may be too strong) about the optimality of deposit insurance will illuminate the more general reasons why it is desirable. We argue in the conclusion that deposit insurance and the Federal Reserve discount window provide nearly identical services in the context of our model but confine current discussion to deposit insurance.

PROPOSITION 2: Demand deposit contracts with government deposit insurance achieve the unconstrained optimum as a unique Nash equilibrium (in fact, a dominant strategies equilibrium) if the government imposes an optimal tax to finance the deposit insurance.

Proposition 2 follows from the ability of tax-financed deposit insurance to duplicate the optimal consumptions $c_1^1(t) = c_1^{1*}(t)$, $c_2^2(t) = c_2^{2*}(t)$, $c_2^1(t) = 0$, $c_1^2(t) = 0$ from the optimal risk sharing characterized in equation (1). Let the government impose a tax on all wealth held at the beginning of period $T = 1$, which is payable either in goods or in deposits. Let deposits be accepted for taxes at the pretax amount of goods which could be obtained if withdrawn at $T = 1$. The amount of tax that must be raised at $T = 1$ depends on the number of withdrawals then and the asset liquidation policy. Consider the proportionate tax as a function of f, τ: $[0, 1] \to [0, 1]$ given by

$$\tau(f) = \begin{cases} 1 - \dfrac{c_1^{1*}(f)}{r_1} & \text{if } f \leq \bar{t} \\ 1 - r_1^{-1} & \text{if } f > \bar{t}, \end{cases}$$

where $\bar{t}$ is the greatest possible realization of $\tilde{t}$.

The after-tax proceeds, per dollar of initial deposit, of a withdrawal at $T = 1$ depend on f through the tax payment and are identical for

all $f_j \leq f$. Denote these after-tax proceeds by $\hat{V}_1(f)$, given by

$$\hat{V}_1(f) = \begin{cases} c_1^{1*}(f) & \text{if } f \leq \bar{t} \\ 1 & \text{if } f > \bar{t}. \end{cases}$$

The net payments to those who withdraw at $T = 1$ determine the asset liquidation policy and the after-tax value a withdrawal at $T = 2$. Any tax collected in excess of that needed to meet withdrawals at $T = 1$ is plowed back into the bank (to minimize the fraction of assets liquidated). This implies that the after-tax proceeds, per dollar of initial deposit, of a withdrawal at $T = 2$, denoted by $\hat{V}_2(f)$, are given by

$$\hat{V}_2(f) = \begin{cases} \dfrac{R\{1 - [c_1^{1*}(f)f]\}}{1 - f} = c_2^{2*}(f) & \text{if } f \leq \bar{t} \\ \dfrac{R(1 - f)}{1 - f} = R & \text{if } f > \bar{t}. \end{cases}$$

Notice that $\hat{V}_1(f) < \hat{V}_2(f)$ for all $f \in [0, 1]$, implying that no type 2 agents will withdraw at $T = 1$ no matter what they expect others to do. For all $f \in [0, 1]$, $\hat{V}_1(f) > 0$, implying that all type 1 agents will withdraw at $T = 1$. Therefore, the unique dominant strategy equilibrium is $f = t$, the realization of $\tilde{t}$. Evaluated at a realization t,

$$\hat{V}_1(f = t) = c_1^{1*}(t)$$

and

$$\hat{V}_2(f = t) = \frac{[1 - tc_1^{1*}(t)]R}{1 - t} = c_2^{2*}(t),$$

and the optimum is achieved.

Proposition 2 highlights the key social benefit of government deposit insurance. It allows the bank to follow a desirable asset liquidation policy, which can be separated from the cash-flow constraint imposed directly by withdrawals. Furthermore, it prevents runs because, for all possible anticipated withdrawal policies of other agents, it never pays to participate in a bank run. As a result, no strategic issues of confidence arise. This is a general result of many deposit insurance schemes. The proposition may be too strong, as it allows the government to follow an unconstrained tax policy. If a nonoptimal tax must be imposed, then when t is stochastic there will be some tax distortions and resource costs associated with government deposit insurance. If a sufficiently perverse tax provided the revenues for insurance, social welfare could be higher without the insurance.

Deposit insurance can be provided costlessly in the simpler case where t is nonstochastic, for the same reason that there need not be a suspension of convertibility in equilibrium. The deposit insurance guarantees that type 2 agents will never participate in a run; without runs, withdrawals are deterministic and this feature is never used. In particular, so long as the government can impose *some* tax to finance the insurance, no matter how distortionary, there will be no runs and the distorting tax need never be imposed. This feature is shared by a model of adoption externalities (see Dybvig and Spatt, in press) in which a Pareto-inferior equilibrium can be averted by an insurance policy which is costless in equilibrium. In both models, the credible promise to provide the insurance means that the promise will not need to be fulfilled. This is in contrast to privately provided deposit insurance. Because insurance companies do not have the power of taxation, they must hold reserves to make their promise credible. This illustrates a reason why the government may have a natural advantage in providing deposit insurance. The role of government policy in our model focuses on providing an institution to prevent a bad equilibrium rather than a policy to move an existing equilibrium. Generally, such a policy need not cause distortion.

VI. Conclusions and Implications

The model serves as a useful framework for analyzing the economics of banking and associated policy issues. It is interesting that the problems of runs and the differing effects of suspension of convertibility and deposit insurance manifest themselves in a model which does not introduce currency or risky technology. This demonstrates that many of the important problems in banking are not necessarily related to those factors, although a general model will require their introduction.

We analyze an economy with a single bank. The interpretation is that it represents the financial intermediary industry, and withdrawals represent net withdrawals from the system. If many banks were introduced into the model, then there would be a role for liquidity risk sharing between banks, and phenomena such as the Federal Funds market or the impact of "bank-specific risk" on deposit insurance could be analyzed.

The result that deposit insurance dominates contracts which the bank alone can enforce shows that there is a potential benefit from government intervention into banking markets. In contrast to common tax and subsidy schemes, the intervention we are recommending provides an institutional framework under which banks can operate smoothly, much as enforcement of contracts does more generally.

The riskless technology used in the model isolates the rationale for deposit insurance, but in addition it abstracts from the choice of bank loan portfolio risk. If the risk of bank portfolios could be selected by a bank manager, unobserved by outsiders (to some extent), then a moral hazard problem would exist. In this case there is a trade-off between optimal risk sharing and proper incentives for portfolio choice, and introducing deposit insurance can influence the portfolio choice. The moral hazard problem has been analyzed in complete market settings where deposit insurance is redundant and can provide no social improvement (see Kareken and Wallace 1978; Dothan and Williams 1980), but of course in this case there is no trade-off. Introducing risky assets and moral hazard would be an interesting extension of our model. It appears likely that some form of government deposit insurance could again be desirable but that it would be accompanied by some sort of bank regulation. Such bank regulation would serve a function similar to restrictive covenants in bond indentures. Interesting but hard to model are questions of regulator "discretion" which then arise.

The Federal Reserve discount window can, as a lender of last resort, provide a service similar to deposit insurance. It would buy bank assets with (money creation) tax revenues at $T = 1$ for prices greater than their liquidating value. If the taxes and transfers were set to be identical to that of the optimal deposit insurance, it would have the same effect. The identity of deposit insurance and discount window services occurs because the technology is riskless.

If the technology is risky, the lender of last resort can no longer be as credible as deposit insurance. If the lender of last resort were *always* required to bail out banks with liquidity problems, there would be perverse incentives for banks to take on risk, even if bailouts occurred only when many banks fail together. For instance, if a bailout is anticipated, all banks have an incentive to take on interest rate risk by mismatching maturities of assets and liabilities, because they will all be bailed out together.

If the lender of last resort is not required to bail out banks unconditionally, a bank run can occur in response to changes in depositor expectations about the bank's credit worthiness. A run can even occur in response to expectations about the general willingness of the lender of last resort to rescue failing banks, as illustrated by the unfortunate experience of the 1930s when the Federal Reserve misused its discretion and did not allow much discounting. In contrast, deposit insurance is a binding commitment which can be structured to retain punishment of the bank's owners, board of directors, and officers in the case of a failure.

The potential for multiple equilibria when a firm's liabilities are

more liquid than its assets applies more generally, not simply to banks. Consider a firm with illiquid technology which issues very short-term bonds as a large part of its capital structure. Suppose one lender expects all other lenders to refuse to roll over their loans to the firm. Then, it may be his best response to refuse to roll over his loans even if the firm would be solvent if all loans were rolled over. Such liquidity crises are similar to bank runs. The protection from creditors provided by the bankruptcy laws serves a function similar to the suspension of convertibility. The firm which is viable but illiquid is guaranteed survival. This suggests that the "transformation" could be carried out directly by firms rather than by financial intermediaries. Our focus on intermediaries is supported by the fact that banks directly hold a substantial fraction of the short-term debt of corporations. Also, there is frequently a requirement (or custom) that a firm issuing short-term commercial paper obtain a bank line of credit sufficient to pay off the issue if it cannot "roll it over." A bank with deposit insurance can provide "liquidity insurance" to a firm, which can prevent a liquidity crisis for a firm with short-term debt and limit the firm's need to use bankruptcy to stop such crises. This suggests that most of the aggregate liquidity risk in the U.S. economy is channeled through its insured financial intermediaries, to the extent that lines of credit represent binding commitments.

We hope that this model will prove to be useful in understanding issues in banking and corporate finance.

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