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ABSTRACT

Diamond-Dybvig [1983] provide a model of intermediation in which bank runs are driven by pessimistic depositor expectations. Models which address these issues are important in the ongoing discussion which weighs the costs (incentive problems) and the benefits (preventing runs) of deposit insurance. In the present paper we extend the Diamond-Dybvig analysis to consider several important questions for evaluating deposit insurance that could not be addressed within their framework. First, we provide conditions for runs when banks can invest in both illiquid and liquid projects. This results in a weakening of the conditions necessary for bank runs relative to the Diamond-Dybvig model in which no liquid investments occur in equilibrium. Second, we characterize how banks respond to the possibility of runs in their design of deposit contracts and investment decisions, particularly through the holding of excess reserves. Finally, we use this framework to evaluate the costs and benefits of deposit insurance and other forms of intervention. To do so, we introduce moral hazard and monitoring into the model to explore the incentive effects of deposit insurance. The implementation of a capital requirement can, along with deposit insurance, support the optimal allocation.

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BANK RUNS: Liquidity and Incentives

I. Introduction

Recent events have called into question the health of certain sectors of the American financial industry. The Savings & Loan crisis threatens to transfer a huge amount of bad debt onto taxpayers shoulders.[1] Banks too seem vulnerable, as the currently small number of failures seems ready to explode.

In light of this experience, many economists and policymakers have quite naturally been looking for the causes of the current crisis. Central to many of these discussions is the role of deposit insurance, created in the United States during the Great Depression (1933) to restore depositor confidence in financial institutions. Despite these insurance benefits, federal deposit insurance may encourage excessive risk taking by the managers of financial intermediaries without providing incentives for monitoring by depositors.[2]

As one would expect, there have been calls to reform deposit insurance and even demands that it be abolished. Any calculation of the optimal extent of deposit insurance, however, must take into account the problems that it was created to solve -- avoiding banking panics. That is, the optimal scheme must weigh the benefits of avoiding runs against the incentive costs. To do so requires a framework for understanding the insurance and incentive effects of deposit insurance.

Our starting point for the development of this framework is the insightful paper of

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[1] Volumes have been written about the S&L crisis. Interesting discussion of the sources of the problem and proposed resolutions can be found in Feldstein [1991] and Kormendi et al. [1989].

[2] Americans are not alone in this regard. Canada established a similar system of deposit insurance in 1967 and there is concern that excessive risk-taking and insufficient monitoring plague the Canadian financial industry as well. See, for example, the interview with Professor John Chant in Financial Times of Canada, January 21, 1991, p. 35.

Diamond-Dybvig [1983]. They present a model in which banks provide liquidity to depositors who are, ex ante, uncertain about preferences over consumption sequences. The deposit contract provides insurance to depositors and supports a Pareto-optimal allocation of the risk. However, a second, inefficient equilibrium exists in which bank runs are driven by pessimistic depositor expectations. Diamond-Dybvig argue that the presence of deposit insurance rules out these Pareto-inferior Nash equilibria.

From a theoretical perspective, while Diamond-Dybvig talk about the role of liquid and illiquid investments, in their actual model, the liquid investment technology is completely dominated by the illiquid technique. In fact, their model demonstrates the insurance aspect of intermediaries and not the role of intermediation in providing liquidity: the investment portfolio of the intermediary is identical to that which private agents would select in autarky. In our model, we introduce a non-trivial investment choice into the bank's optimization problem. This results in new conditions for bank runs equilibria which rely jointly on the costs of liquidating the long term investment and, as in Diamond-Dybvig, the risk aversion of depositors. This addition to the model also enables us to examine the affect of the perceived likelihood of a run on an intermediary's investment decisions.

Second, Diamond-Dybvig do not analyze the impact of runs on the behavior of banks, either in terms of the optimal deposit contract or their investment portfolio. That is, in the contracting stage of the Diamond-Dybvig model, agents do not perceive the possibility that a run might occur.[3] We model the ex ante choice of deposit contract and bank portfolio given that a run, modelled as a sunspot which correlates the beliefs of depositors, might occur ex post.

[3] Diamond-Dybvig do note that in the ex ante contracting stage the chance of runs could be modeled as a sunspot but never pursue the implications of this for the design of the contract.

If the likelihood of a run is sufficiently high, the optimal contract will avoid runs altogether. Otherwise, the optimal contract may allow the possibility of equilibrium bank runs. Banks respond to the possibility of runs by adjusting their portfolios. If liquidation costs are sufficiently high, intermediaries will desire more liquidity ex ante and will thus hold excess reserves. This is consistent with the observation in Friedman-Schwartz [1963, pgs. 176 and 333] that during periods of instability in the banking system, the deposit reserve ratio tends to fall.

After constructing a model in which bank runs may arise, we evaluate the costs and benefits of deposit insurance. Following Diamond-Dybvig, deposit insurance eliminates the possibility of runs. To understand the costs of this insurance, we introduce a moral hazard problem into the bank's portfolio decision. Deposit insurance avoids bank runs but has adverse incentive effects: it implies less monitoring by investors which allows banks to hold riskier portfolios. In the absence of this insurance, runs are possible even though banks respond by adjusting the terms of their contracts and investment portfolios. Thus a tradeoff emerges between insurance against bank runs and monitoring incentives. By characterizing this tradeoff, our model provides insights into the costs and benefits of deposit insurance. Finally, we argue that it is possible to use deposit insurance to eliminate bank runs without creating moral hazard problems as long as a capital requirement on intermediaries is imposed.

II. Model

The model we use to analyze these issues is a modified version of that developed by

Diamond-Dybvig [1983].[4] The key difference between the models lies in the nature of the technology; in particular, in the specification of liquidation costs. This apparently small alteration in their model has interesting implications in terms of the conditions for bank runs and the optimal portfolio of the intermediary.

Consider an economy in which N agents live for, at most, three periods. In period 0, all agents decide whether to deposit funds in an intermediary or to invest their unit endowment themselves. At the start of period 1, a proportion π of the agents learn that they obtain utility from period 1 consumption only while the other agents obtain utility from period 2 consumption. These agents are referred to as early and late consumers. This is a tractable means to model the uncertain liquidity needs of agents. Assume that π is known to all agents so that there is individual uncertainty over tastes but no aggregate uncertainty.[5] Let c_E and c_L be the consumption levels for early and late consumers respectively and $U(c_i)$ for $i=E,L$ is their utility function over consumption. Assume that $U(\cdot)$ is strictly increasing and strictly concave, $U'(0)=\infty$ and set $U(0)=0$.

The technology available to agents is given in the table below. The illiquid investment provides a productive means of moving resources from period 0 to 2, with a return of $R>1$ over the two periods. However, liquidation of projects using this technique yields $1-\tau$ in period 1,

[4] Some of these modifications also appear in the closely related paper by Freeman [1988]. In particular, Freeman also introduces a non-trivial portfolio choice of the intermediary and investigates the response of the private sector to the possibility of bank runs. Our model of the bank's response to runs is different than Freeman's, as described below. Further, we investigate the moral hazard implications of deposit insurance and the benefits of this insurance when bank runs are possible.

[5] This follows the first part of Diamond-Dybvig. In the last part of their paper they consider the importance of aggregate uncertainty to argue further in favor of deposit insurance.

where $\tau \epsilon [0,1]$. Diamond-Dybvig assume that $\tau=0$, thus ignoring these liquidation costs.[6] This type of project represents a long-term investment in plant and equipment with a relevant time-to-build component. While liquidated projects are not necessarily worthless, there are certainly some costs associated with conversion to their original state.[7]

Period	0	1	2
Endowment	1	0	0
Illiquid Investment	-1	$1-\tau$	R
Liquid Investment	-1	1	1

The liquid technique is not as productive as an illiquid investment. On the other hand, it provides for period 1 consumption without a liquidation cost. This technique can also be used as storage (with a zero return) from period 1 to 2. One might think of government debt as a liquid but relatively low return asset.

Suppose first that there are no intermediaries in the economy so that individual agents allocate their endowment across the two types of investment before knowing their preferences. Let i be the amount of the endowment placed in the illiquid investment. Agents choose i to solve:

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[6] At the other extreme, Jacklin-Bhattacharya [1988] consider the case of $\tau=1$. More recent versions of this model, such as Wallace [1988,1990], dispense with the two technique specification altogether and just assume that the return on storage between periods 0 and 1 differs from that between periods 1 and 2.

[7] In fact, one could imagine that the magnitude of τ would be market determined in a more general economic model. This would provide an interesting link between the state of the aggregate economy and the optimal contract.

$$\max_{i} \quad \pi U(c_E) + (1-\pi)U(c_L)$$

s.t.

$$c_E = 1-\tau i \tag{1}$$

and

$$c_L = iR+(1-i).$$

An interior solution satisfies

$$\tau\pi U'(1-\tau i) = (1-\pi)(R-1)U'(Ri+(1-i)). \tag{2}$$

Let V^A be the expected utility from autarky.

Since decisions must be made prior to the realization of tastes, in the event that the agent is an early consumer, illiquid investment must be liquidated. Further, in the event that the agent is a late consumer, c_L is reduced since the agent invested, ex ante, part of his endowment in a relatively unproductive investment. These costs arise due to the absence of ex ante insurance markets or ex post markets in which early consumer could sell the rights to their illiquid investments to the late consumers in return for period 1 output.

One means of providing an efficient allocation of goods is through an ex ante insurance arrangement. We represent this as a planning problem and then discuss the decentralization of the resulting allocation. To begin, assume that agents' types are ex post observable so that consumption can be made contingent upon tastes. The planner's problem is simply to determine consumption levels for each type subject to a resource constraint in each period. The planner chooses the per capita level of investment in the illiquid investment to solve

$$\max_{i} \quad \pi U(c_E) + (1-\pi)U(c_L)$$

$$s.t. \tag{3}$$

$$\pi c_E = (1-i) \text{ and,}$$

$$(1-\pi)c_L = iR.$$

The optimal contract satisfies

$$U'(c_E) = RU'(c_L). \tag{4}$$

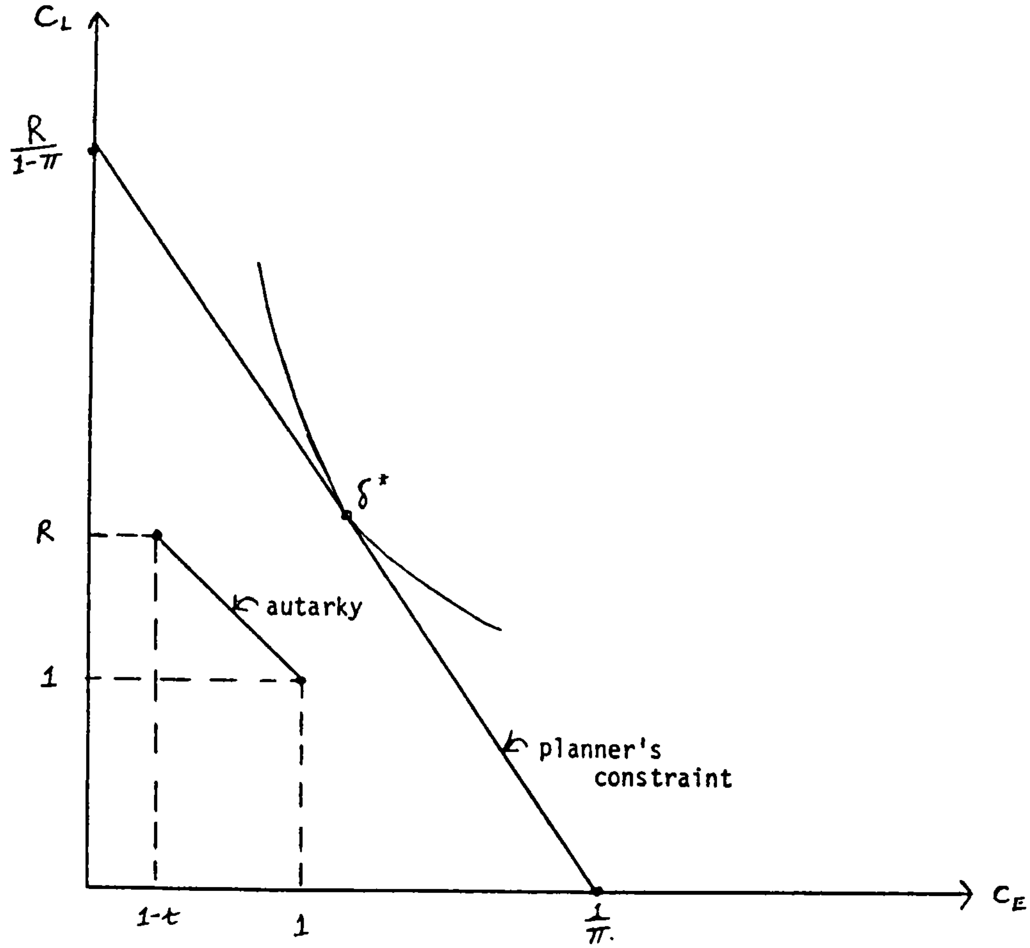
Note that this allocation is independent of τ. In the first best equilibrium, there is no uncertainty and hence no liquidations. Since $R > 1$, the strict concavity of $U(\cdot)$ implies that $c_E < c_L$.

In general, the utility obtained from δ^*, denoted V^*, will exceed that expected utility under autarky, V^A. The autarkic allocation is certainly feasible for the planner but is clearly never chosen since there are no liquidations under δ^*. Thus for $\tau \neq 0$, $V^* > V^A$. The planner provides insurance against the randomness of preferences and provides liquidity to early consumers without the need to liquidate the higher return investment.

If $\tau = 0$, as in Diamond-Dybvig, $i = 1$ in both problems. In this case, relative to autarky, there is no provision of liquidity by the planner, just insurance. With $\tau = 0$, the autarkic consumption profile is (1,R) and this will not generally satisfy (4).[8]

The optimal allocation is shown by δ^* in Figure 1. The resource constraint for the planner is indicated by the negatively sloped line with a vertical intercept of $R/(1-\pi)$ and a

[8] For preferences exhibiting constant relative risk aversion (σ), the consumption profile (1,R) will satisfy (4) iff $\sigma = 1$.



C_L
$\frac{R}{1-\pi}$
δ^*
R
autarky
1
planner's constraint
1-t
1
$\frac{1}{\pi}$
C_E

Figure 1

horizontal intercept of $1/\pi$. The combinations of (c_E,c_L) that are feasible under autarky are shown as well. Note that the autarkic allocations are feasible but not desired for the planner.

This allocation can be decentralized through an intermediary. The intermediary takes deposits and in period 0 offers a contract stipulating a type-specific return per unit of period 0 investment of $\delta^*=(c_E^*,c_L^*)$ to depositors.[9] In this contract, (c_E^*,c_L^*) solve (3). This intermediary breaks even in equilibrium and no other intermediary could offer a contract which is preferred by the agents in period 0 and yields non-negative expected profits. It is also possible to think of δ^* as being the contract offered by a large number of intermediaries: due to constant returns to scale the number of active intermediaries is not determined.

An interpretation including multiple intermediaries introduces interesting complications to the model. First, there is the possibility of interbank flows which could provide additional liquidity to individual banks.[10] Second, there is the question of whether bank runs are system-wide or intermediary specific. In this paper, we focus on the single bank case. Equivalently, we ignore interbank loans and assume bank runs are system-wide. This allows us to capture the systemic element of panics but implies that we are unable to model a process under which runs begin at a few banks and then spread through the system.

So far this discussion assumes that preferences are observable ex post. The interesting part of the analysis occurs when tastes are private information. That is, suppose that at the start of period 1, when agents learn their preferences, tastes are not observable to the planner (or the

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[9] Jacklin [1987], Jacklin-Bhattacharya [1988] and Postlewaite-Vives [1987] discuss other, more general contracts, that may not have some of the problems associated with deposits contracts. For example, Postlewaite-Vives mention contingent contracts in which the payment could depend on the amount withdrawn by others in that period. This is, in fact, a variant of the suspension of convertibility. Jacklin [1987] and Jacklin-Bhattacharya [1988] argue that equity contracts may also support the optimal allocation. Calomiris-Kahn [1991] argue that demand deposits are a desirable form of bank liability as they, along with sequential service, provide an incentive for monitoring by depositors.

[10] See Chari [1989] for a discussion along these lines.

intermediary).

The problem now has three stages. First, the contract is set by the planner. Contracts specify a consumption level for each type of consumer independent of the number of consumers claiming to be each type. Second, agents learn their preferences and these are announced to the planner. Without loss of generality, we employ a direct revelation mechanism in which the agents report their taste types to the central authority.[11] Finally, the allocation of goods to agents is determined by the contract.[12]

Consider first the implementation of δ^*. In the game, truthtelling is a dominant strategy for early consumers since they have no value for goods delivered in period 2. From the viewpoint of the late consumers, truthtelling is a best response to truthtelling by all other late consumers. If a single late consumer misrepresents preferences, then this agent will receive, at most, c_E in period 1 which can be privately stored until period 2. However, under δ^*, $c_L > c_E$ so that this misrepresentation by a single agent is not optimal. Thus the optimal allocation can be achieved under δ^* as a Nash equilibrium in which all agents honestly report their true tastes.

Interestingly enough, it is possible that another equilibrium exists in the second stage game under δ^*. In this candidate equilibrium all late consumers misrepresent their tastes and announce that they are early consumers. This can be an equilibrium if the planner does not have sufficient resources (including liquidated illiquid investments) to provide c_E to all agents.

In the decentralized problem, this equilibrium with misrepresentation is termed a "bank

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[11] In the decentralized model, discussed below, agents will sequentially arrive at an intermediary to obtain funds and no direct revelation will arise. For the planner's problem, the restriction that the consumption level for each type is independent of the number announcing that type is a means of mimicking sequential service.

[12] In the discussion that follows, we call the first stage the "contract" and the second stage the "game". As discussed below, due to private information, it is now possible that the intermediary is unable to provide c_L to all late consumers. In that event, they share the liquidated value of the intermediary.

run." Under the assumption of sequential service, individuals arrive at the bank and obtain c_E until the intermediary's resources are exhausted.[13] Contracts in which c_E is contingent on the total number of agents in line (claiming to be early consumers) are not consistent with sequential service. The conditions for runs and their implications are described next.

Let N^r be the number of depositors receiving payment under a run and $p(\tau)$ be the ratio of N^r to N. When $N^r \leq N$, $p(\tau)$ is the probability of being served if all agents run as a function of the liquidity cost. N^r and $p(\tau)$ are defined relative to an existing contract which is suppressed in the notation. The resource constraint for the intermediary implies $N^r c_E = (1-i)N + Ni(1-\tau) = N(1-i\tau)$ so that $p(\tau) = (1-i\tau)/c_E$. Under the first-best contract, δ^*, $p(\tau) = (1-i\tau)\pi/(1-i)$ where i is determined by (4).

Note that $p(\tau)$ is an increasing function of i for $\tau < 1$. As i increases, $p(\tau)$ is influenced in two ways. First, for given c_E, an increase in i reduces $p(\tau)$ for $\tau > 0$ since liquidation costs are higher. However, an increase in i lowers c_E so that more agents can be served, i.e. $p(\tau)$ increases. For $\tau < 1$, the second effect dominates.

Proposition 1: A runs equilibrium exists iff $p(\tau) < 1$.

Proof: Suppose that $p(\tau) < 1$. Then if all other late consumers run, the remaining late consumer should too since this yields a chance at obtaining c_E from the bank. If the remaining late consumer does not run, he will receive 0 for sure in the second period. So $p(\tau) < 1$ implies that a runs equilibrium exists.

Suppose that $p(\tau) \geq 1$. Then, even if all other agents announce they are early consumers,

[13] Wallace [1988] provides a useful camping trip parable for the sequential service constraint.

the remaining late consumer should not run since that agent will receive at least c_E in the next period. Thus for a run to occur it cannot be the case that $p(\tau) \geq 1$. QED.

Note that the condition for runs depends on two important variables: the size of the liquidation cost, τ, and the level of investment in the illiquid investment (or, equivalently, c_E).

Clearly $p(\tau)$ is a decreasing function of τ since, from (4), i^* is independent of τ. At $\tau=1$, there will be a runs equilibrium for all concave $U(\cdot)$ since $p(1)=\pi<1$. In contrast to the results reported in Diamond-Dybvig, runs do not require very risk averse agents.

From the conditions describing δ^*, c_E is an increasing function of the degree of consumer's risk aversion but is independent of τ. This leads to

Proposition 2: $p(\tau)$ is a decreasing function of consumer risk aversion.

Proof: By definition, $p(\tau)$ is a decreasing function of c_E. Consider a utility function $W(c) \equiv F(U(c))$ where $F(\cdot)$ is strictly increasing and strictly concave. A consumer with preferences given by $W(\cdot)$ is more risk averse than an agent with preferences represented by $U(\cdot)$. From this construction and (4), $W'(c_E^*)/RW'(c_L^*)=F'(U(c_E^*))/F'(U(c_L^*))>1$ as $F(\cdot)$ is concave and $c_L^*>c_E^*$. With preferences given by $W(\cdot)$, the conditions for optimality thus require a lower level of illiquid investment and thus a higher level of early consumption than in the economy with preferences represented by $U(\cdot)$. Thus an increase in consumer risk aversion increases c_E and lowers $p(\tau)$ for all values of τ. QED.

As a useful example, suppose that $U(c)=c^{1-\sigma}/1-\sigma$, so that the degree of relative risk aversion for this agent is σ. For these preferences, the optimal allocation satisfies:

$$(c_L/c_E)^{\sigma} = R \tag{5}$$

Figure 2 illustrates the combinations of τ and σ such that an equilibrium with runs will exist.

At $\sigma=1$, which is the borderline condition in the Diamond-Dybvig model, the solution is $c_E=1$, $c_L=R$ and $i=1-\pi$. If, in addition, $\tau=0$, then the economy will not have a bank runs equilibrium. At $\tau=0$, increasing σ implies that c_E must increase so that p(0) is less than 1 and a runs equilibrium will exist.[14] For $\sigma\leq 1$, $p(\tau)$ will be less than 1 for large enough τ so that, in contrast to Diamond-Dybvig, a runs equilibrium exists even if consumers are not too risk averse.

So, introducing the non-dominated liquid asset has an interesting effect on the runs condition. The requirements on the degree of risk aversion can be weakened, relative to those reported by Diamond-Dybvig, if there is a cost of liquidating the high return project. In general, runs will occur for sufficiently large liquidation costs and when consumers are sufficiently risk averse.

III. The Implications of Runs

Given that runs may occur, it is natural to return to the first-stage of the optimization problem and consider the implications of this possibility for the design of the contract. Here, as in many abstract mechanism design problems, an important issue arises: how is an optimal

[14] From the resource constraint, c_E is a decreasing function of i and c_L increases with i. Hence, in order for (5) to hold, an increase in σ must be offset by a reduction in i so that c_E increases and c_L decreases.

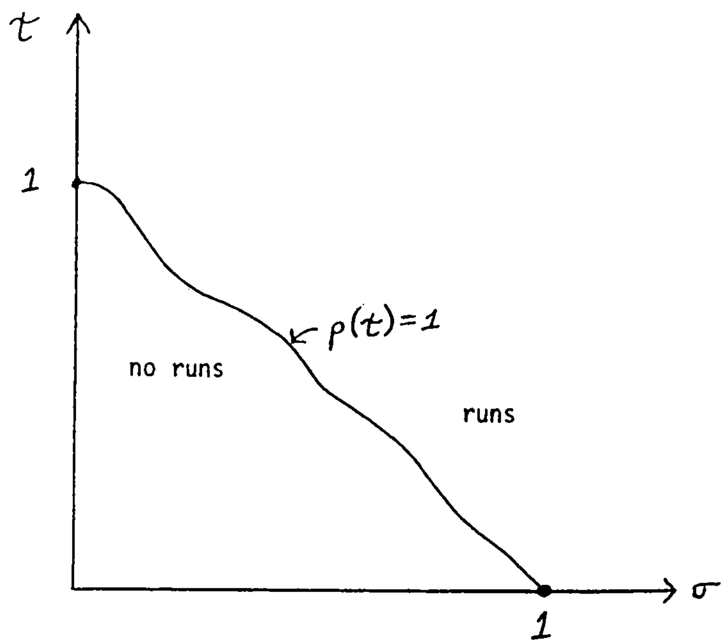

Figure 2

contract designed given that there may be multiple equilibria in the stage game that ensues once the terms of the contract have been set?[15]

At one extreme, one might look at contracts for which there is a unique Nash equilibrium in the game. These contracts are feasible but, as we shall see, may create costly distortions. Alternatively, one might construct a model of the equilibrium selection process and solve for the optimal contract. One simple model relies on the existence of publicly observable, but not contractible, variables (sunspots) that correlate agents behavior at a particular equilibrium of the game.[16] Instead of preventing runs, the intermediary adjusts the contract and its portfolio to reduce the impact of runs in the event they arise.

To determine whether the optimal contract allows for runs, one could study a general optimization problem in which the intermediary could choose either a contract where runs occur with some probability or a runs preventing contract. Our approach is to consider the best contract given that liquidations (not runs) occur with an exogenous probability of q. We then compare the resulting expected utility against that from a contract that prevents runs to see which type of contract is optimal. Essentially we study the two branches of the larger problem separately and then compare them.

In analyzing these contracts two issues are important. First, what is the implication of the possibility of a liquidation on the portfolio of the intermediary? In particular, is there more or less investment in the illiquid technique relative to the first-best allocation. Second, when is it optimal to choose a contract that prevents runs with probability one?

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[15] See the discussions of this class of problems in Palfrey and Srivastava [1987], Ma [1988] and Ma, Moore and Turnbull [1988].

[16] Bental et al. [1990] and Freeman [1988] also adopt a sunspots approach. In contrast to our work, those papers allow for sunspot contingent contracts. While it is convenient to think of sunspots as determining which equilibrium of the subgame will be observed, contracts contingent on these events are assumed to be infeasible.

A. Runs Preventing Contracts

Consider first a runs preventing contract, hereafter RPC, for which there is no equilibrium with runs. To make the analysis interesting, assume that a runs equilibrium exists under δ^*. The set of RPC contracts is obtained by making two modifications to the constraints in (3). First, we add the condition that $p(\tau) \geq 1$ to ensure that truthtelling is the only Nash equilibrium for the portfolio and the consumption allocation chosen in this problem. Second, we allow the planner or intermediary to hold liquid investment, denoted by i_2, over two periods: this was feasible but clearly not desirable when types were observable.

In finding the best runs preventing contract, however, holding excess reserves might be necessary in order to provide desired levels of c_E while still preventing runs. As an extreme example, suppose that $\tau=1$. Then, if excess liquidity is not possible, $c_E=0$ is the only early consumption level that is runs proof.[17] However, the (1,1) allocation is feasible if the intermediary sets $i=0$ and holds liquid assets between periods 1 and 2 yielding, for some preferences, a better outcome.

Formally, consider the following three conditions:

$$\begin{aligned} \pi c_E &= 1-i-i_2 \\ (1-\pi)c_L &= iR+i_2 \\ c_E &\leq 1-i\tau. \end{aligned} \tag{6}$$

The first two are resource constraints and the third is the no runs condition. These, plus the

[17] The no runs condition implies that $c_E = 1\text{-}i$ and the feasibility condition is $c_E=(1\text{-}i)/\pi$. For both of these to hold implies that $i=1$ and hence $c_E=0$.

non-negativity conditions, determine the set of (c_E,c_L) that are runs proof.

Figure 3 depicts this set as the shaded region. Since $i \geq 0$ and $\tau \geq 0$, c_E cannot exceed 1 so there is a vertical segment at $c_E=1$. Then there is a segment from (1,1) to $((1-\tau)/(1-\pi\tau), R/(1-\pi\tau))$, denoted by point A in Figure 3. This segment of the boundary of the set lies below the resource constraints from (3). That is, there are allocations which, from (3), satisfy the resource constraints, but are not runs proof. In this segment, $i_2 > 0$; allocations here require that excess liquidity be held to support a relatively high level of c_E while avoiding runs. A third segment coincides with the resource constraint for $c_E < (1-\tau)/(1-\pi\tau)$. In this region, the runs prevention constraint is not binding as c_E is sufficiently low. It is straightforward to check that the allocations that were feasible under autarky are also in the set of runs preventing contracts. Thus the best runs preventing contract, δ^{nr}, will (weakly) dominate autarky: intermediaries can prevent runs and improve upon autarky, i.e. $V^{nr} > V^A$.

At $\tau=0$, $c_E=1$ and $c_L=R$ and there will be no excess liquidity. When there are no liquidation costs, the set of runs proof allocations is the intersection of the (c_E,c_L) pairs that satisfy the resource constraint and those that satisfy $c_E \leq 1$. This is shown in Figure 4. Since, by assumption, δ^* is not runs proof, the concavity of $U(\cdot)$ implies that the optimal allocation will occur at (1,R). In this case, which corresponds to the parameter values assumed by Diamond-Dybvig, this is the same allocation as that obtained under autarky.

At the other extreme, for $\tau=1$, the set of feasible allocations is shown in Figure 5. In this case the optimal contract will involve the holding of excess liquidity since, at $\tau=1$, $i_2=0$ and the no runs condition would imply that $c_E=0$. $U'(0)=\infty$ implies that this is suboptimal so that $i_2 > 0$ in the best runs preventing contract.

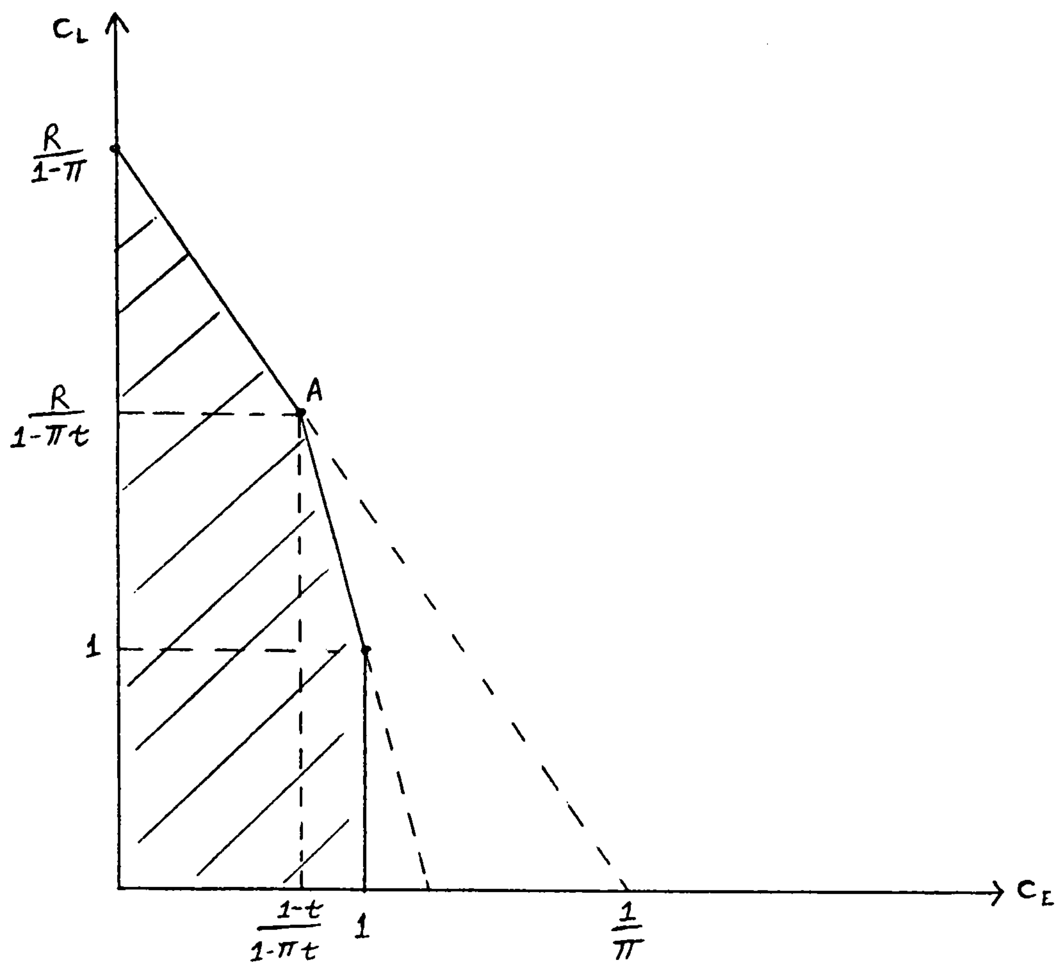

Figure 3

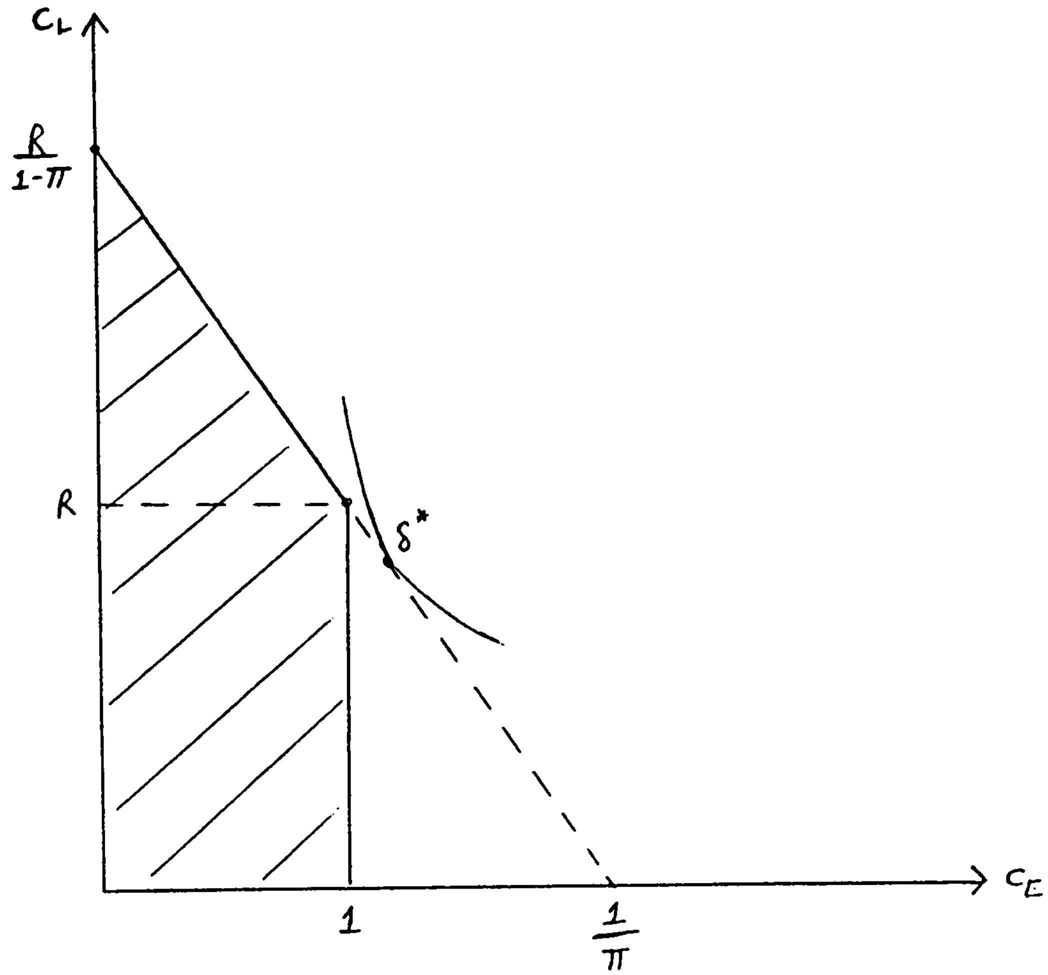

Figure 4

RPC with $\tau=0$

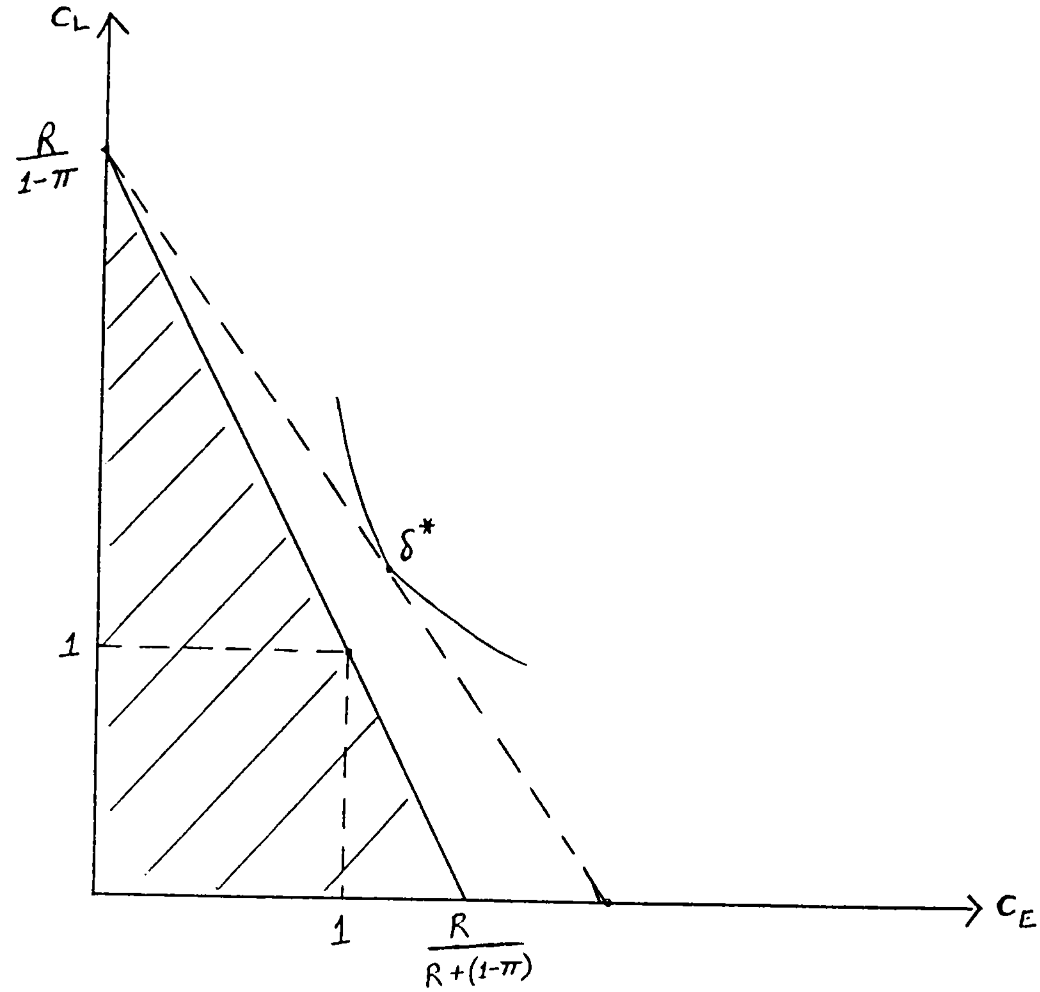

Figure 5

RPC with τ=1

In general, the best runs preventing contract will always dominate the best allocation obtainable under autarky. When τ is sufficiently large, the amount of liquid investment will exceed c_E. This allows the intermediary to provide c_E without violating the conditions for no runs. As suggested by Figure 3, excess liquidity will be held when the consumer's marginal rate of substitution at point A exceeds the slope of the middle segment of the feasibility constraint, given by $-((R+\pi-1)/\tau(1-\pi))$.

In addition to generating a demand for excess liquidity, the best RPC will distort consumption. Formally:

<u>Proposition 3:</u> In the best runs preventing contract, early consumption is less than early consumption in the first best contract, δ^*.

Proof: δ^{nr} will either be at point A in Figure 3 or along the segment from that point to (1,1). Since, by assumption, runs occurred under δ^*, if δ^{nr} is at A, early consumption is less under δ^{nr} than in δ^*. If δ^{nr} is on the segment between A and (1,1), given that c_E and c_L are normal goods and the segment between A and (1,1) is steeper than the resource constraint, income and substitution effects imply that early consumption must be lower under δ^{nr}. QED.

B. Contracts with Runs

In contrast to the best RPC, we now consider the optimal contract when liquidation occurs with probability q. To pursue this alternative, suppose that with probability q, there is a wave of economy-wide pessimism that determines the beliefs of depositors. If the outstanding contract has a runs equilibrium, then the pessimism leads to a bank run. With probability 1-q, there is optimism and no runs. Of course, if the contract yields $p(\tau) \geq 1$, then the outcome of the sunspot will have no impact on behavior. In this way, the beliefs of depositors are tied to a move of nature which determines their actions. The intermediary recognizes this dependence in designing the optimal contract.

Given q, the intermediary would either choose a contract which prevents runs or one in which runs occur with probability q. To understand this choice, we consider the optimal contract when liquidations occur with probability q and then compare this against V^{nr} as given above. The maximum over these two expected utility levels determines the optimal contract.

Taking the probability of liquidation, q, as given, the contract solves

$$\max_{c_E, c_L, i, i_2} \quad (1-q)[\pi U(c_E) + (1-\pi)U(c_L)] + q\,U(c_E)\left(\frac{1-i\tau}{c_E}\right)$$

$$s.t.$$

$$\pi c_E = 1 - i - i_2 \tag{7}$$

$$(1-\pi)c_L = iR + i_2$$

$$i_2 \geq 0.$$

Let $\delta(q)$ be the contract solving this problem and V(q) denote the resulting expected utility.

Using λ^i for i=E,L as the multipliers on the resource constraints and β as the multiplier on the non-negativity constraint for second period liquid investment, the necessary conditions for an optimal solution are given by:

$$
\begin{aligned}
(1-q)\pi U'(c_E) + q\left[\frac{N^R}{N}(U'(c_E) - \frac{U(c_E)}{c_E})\right] &= \lambda^E \pi \\
(1-q)(1-\pi)U'(c_L) &= \lambda^L(1-\pi) \\
\frac{q\tau}{c_E}U(c_E) + \lambda^E &= \lambda^L R \\
\lambda^L + \beta &= \lambda^E.
\end{aligned}
\tag{8}
$$

To understand the effects of liquidations on investment, we begin by assuming that $i_2=0$. We then relax this simplifying assumption.

With $i_2=0$, these first order conditions can be combined to yield

$$(1-q)[RU'(c_L) - U'(c_E)] = q\frac{N^R}{N\pi}\frac{U(c_E)}{c_E}\left[\frac{U'(c_E)c_E}{U(c_E)} - (1-\phi(\tau))\right]. \tag{9}$$

where $\phi(\tau) \equiv \tau\pi N/N^R = \tau(1-i)/(1-i\tau)$. The last equality comes from the definition of N^R/N.

Using this condition, we find

Proposition 4: In the solution to (7) with $i_2=0$, for τ near 0, the amount of illiquid investment is higher than under the first best contract and for τ near 1 the amount of illiquid investment is lower than under the first best.

Proof: First, suppose that $\tau=0$ implying $\phi=0$. This implies that the right side of (9) is negative since $U(\cdot)$ is strictly concave. Hence, $RU'(c_L) < U'(c_E)$ which implies that c_E is less than its first-best level due to a lower level of investment in the liquid asset. This is true by continuity for τ near 0.

Second, suppose that $\tau=1$ implying $\phi=1$ so that the right side of (9) is positive. Thus $RU'(c_L) > U'(c_E)$ implying that c_E is greater than its first-best level. For this to occur requires that the liquid investment level be higher than the first-best level. This is true by continuity for τ near 1. QED.

The proposition is a bit surprising in that it is not always the case that the possibility of bank runs leads to more investment in the liquid technique. The effect of runs on the optimal portfolio depend on τ. To gain some intuition, consider a slightly different problem of allocating a fixed supply of goods to a group of consumers with strictly concave utility functions where social welfare is the sum of individual utilities (as it is in the bank's optimization problem here). It is always feasible to give commodities to only a subset of the agents but, given the strict concavity of the utility function, this is sub-optimal. The optimal allocation will provide equal consumption to all agents.

A similar influence is at work in the case of bank runs: it is desirable in the bank run state to have a low level of c_E so that all agents can receive some of the goods. However, there are other factors at work. First, banks also desire to avoid large liquidation costs in the event of runs. This leads them to hold a more liquid portfolio. Second, from the perspective of allocating goods efficiently in the no bank runs state between early and late consumers, a higher value of c_E is desired. As suggested by the proposition, for τ near 1, the liquidation cost effect dominates so that investment in the liquid asset and, hence higher c_E, occurs. For τ near 0, the insurance effect in the bank runs state dominates so that c_E falls relative to its first-best level and illiquid investment rises. In this case, the reduction in early consumption is limited by the efficiency costs in the no bank runs state.

When $i_2>0$ is possible, the bank has the ability to avoid liquidation costs without increasing c_E. This option is particularly valuable for large values of τ and q since the gain to $i_2>0$ arises when runs are likely and liquidation costs are large. We find that

Proposition 5: If $q\tau>(1-q)(R-1)$, then $i_2>0$ in the solution to (7).

Proof: First, using (8),

$$0 \leq \beta = \lambda^E - \lambda^L = (1-q)[U'(c_E) - U'(c_L)] + \frac{qN^R}{\pi N}[U'(c_E) - \frac{U(c_E)}{c_E}] \tag{10}$$

Since $U(\cdot)$ is strictly concave, the last term is negative implying $c_E<c_L$.

Again using the concavity of $U(\cdot)$ and $c_L>c_E$, $q\tau>(1-q)(R-1)$ implies

$$q\tau U(c_E)/c_E > (1-q)(R-1)U'(c_E) > (1-q)(R-1)U'(c_L).$$

Finally, suppose that $i_2=0$ and consider a slight increase in this term with a compensating decline in i so that c_E remains constant. The gain from this change in i_2 will be to increase the proportion of agents who can receive c_E if a run occurs. This is given by $q\tau U(c_E)/c_E$. The cost of increasing i_2 will be to reduce utility for late consumers in the event a run does not occur. This cost is given by $(R-1)U'(c_L)(1-q)$.

Thus, we see that if $q\tau>(1-q)(R-1)$, then the marginal gains to increasing i_2 (starting at

0) outweigh the marginal costs. QED.

This proposition captures the gains to excess liquidity: it allows the banks to separate the level of early consumption from the proportion of agents that can be served in the event of a run. From Proposition 4, where $i_2=0$ by assumption, the intermediary avoided high liquidation costs by raising c_E. This is costly in that the number of agents who can be served in the event of a run is lower and if runs do not occur, $U'(c_E)<RU'(c_L)$; i.e. there is a distortion in consumption. When the bank is allowed to hold excess reserves, it does so if the expected liquidation costs ($q\tau$) are large relative to the difference in returns between the two types of investments (R-1). The holdings of excess reserves are likely when the runs are more probable and liquidation costs are high.

At the other extreme, when τ is near 0, there are no liquidity gains so that $i_2=0$. Formally, we find

Proposition 6: If τ is near 0, then $i_2=0$.

Proof: Suppose that $i_2>0$ and $\tau=0$. Then, $\beta=0$ implying, from (8), that $\lambda^E=\lambda^L$. This contradicts the third condition in (8) since $R>1$. By continuity, the result holds for τ near 0. QED.

In this case, the results of Proposition 4 hold: the effect of the possibility of runs is to reduce c_E so that more agents can be served in the event of a run.

From an empirical perspective, as discussed by Friedman-Schwartz [1963], accounts of panics indicate a drive toward liquidity for banks (through the holding of excess reserves) and by depositors (through increases in the currency/deposit ratio). These types of effects arise in this model because of the dominance of the liquid technology for short-term investments. Hence, for values of τ and q near 1, we find that banks allocate more of their funds to the liquid investment and may hold excess liquidity to provide funds to depositors in the event of a run. While our model is static in that runs can occur in only one period, thinking about the implications of increasing q in our framework is useful for understanding the dynamic implications of runs if the chance of a run in period t+1 increases in the event of a run in period t.

Given this contract, should the bank adopt a runs preventing contract? The relationship between the expected utility from the contract that prevents runs (V^{nr}) and the optimal contract when liquidations occur with probability q, V(q), is given by

Proposition 7: There exists $q^* \epsilon (0,1)$ such that $V^{nr} > V(q)$ if $q > q^*$ and $V^{nr} < V(q)$ if $q < q^*$.

Proof: V(q) is a decreasing function of q as the runs allocation, which is obtained with probability q, was certainly feasible when the contract was chosen. Increases in q put more weight on the consumption profile when liquidation occurs and thus decrease expected utility.

$V(0) > V^{nr}$ since at $q=0$ we obtain the first-best level of expected utility. Since runs are possible under δ^*, this is a different allocation than the runs preventing contract.

Further, $V(1) < V^{nr}$ since $V(1)=U(1)$. To see this, first note that at $q=1$, the best allocation is to invest all deposits in the liquid investment since a liquidation will occur with probability 1. The resulting contract yields both early and late consumers a unit and does not have a runs equilibrium. This allocation was feasible (set $i=0$ and $i_2=1-\pi$) when the runs preventing contract was chosen. However, the optimal runs preventing contract will never be at (1,1) so $V(1)<V^{nr}$.

Since V(q) is continuous in q, there must exist a q^* such that $V(q^*)=V^{nr}$. For $q>q^*$, $V(q)<V^{nr}$ since V(q) is a decreasing function.

QED.

This proposition provides a characterization of the maximum level of utility that depositors can receive from intermediaries if runs occur with probability q and there is no deposit insurance. If the probability of a run is low, then $\delta(q)$ will be the optimal contract. Since V^{nr} is the best runs preventing contract, $V(q)>V^{nr}$ implies that $\delta(q)$ cannot be runs proof so that runs will be observed under the optimal contract. When the probability of runs is sufficiently high, the solution will be to adopt a runs preventing contract. In either case, the process of intermediation will not stop due to the possibility of bank runs.

An important effect of runs under δ^* will be to alter the consumption profile and the investment strategy of the bank; there will be a desire for more liquidity if liquidation costs are sufficiently high and an incentive to alter early consumption. If the probability of a run is sufficiently high, then a runs preventing contract will be adopted which will lower early consumption and, perhaps, require the holding of excess liquidity. If a contract allowing runs is chosen, then for τ large enough, excess liquidity will be held.

IV. Deposit Insurance

Following Diamond-Dybvig, deposit insurance can avoid bank runs in this environment. However, an important cost of deposit insurance is a moral hazard problem, introduced into the model below, associated with the bank's portfolio choice.

Deposit insurance is a contract set by the government that provides a payment to depositors in the event that the bank is unable to pay its obligations. This insurance is paid regardless of the basis for the inability of the bank to pay depositors. That is, deposit insurance, as modeled here, does not distinguish between bank failures due to fundamentals, such as ex post low returns on investments, and runs.

Let C be the payment to depositors in the event of a bank liquidation. For simplicity, assume that the tax obligations to finance C fall on all agents who are not depositors.[18] In this economy, the government selects ξ, a proportion of deposits that it will reimburse. The bank offers a contract and chooses an investment portfolio that satisfy the constraints in (3).[19] Finally, the consumers decide whether to put deposits in the bank or not. Ex post there may be bank runs in period 1 depending on the nature of the deposit contract and the size of ξ. In the event of a run in period 1, depositors not receiving funds from the bank can receive ξc_E from the government.

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[18] Here we do not consider the possibility that intermediaries make payments into a deposit insurance pool but rather focus on the obligations of taxpayers to the system. Wallace [1988] argues that the taxation policy used by Diamond-Dybvig may be inconsistent with the assumption of spatial separation that underlies the sequential service constraint in their model. Here we imagine a government policy which provides ξc_E to depositors who arrive at the bank after the bank has exhausted resources and then taxes, say, the endowment of a group of agents in the economy not involved with the intermediary or even the endowment of the next generation of depositors, as in Freeman [1988], to finance these transfers. The key point is that there must be a government taxation scheme that is not inconsistent with isolation that is capable of generating the needed revenues.

[19] Thus we do not consider the possibility, described in Freeman [1988], that the intermediary and depositors will negotiate an infeasible contract and rely on deposit insurance to provide the additional consumption goods to depositors.

Proposition 8: There will be no bank runs equilibria in this economy if $\xi = 1$.

Proof: The only basis for runs is if late consumers attempt to withdraw funds early. However, if $\xi = 1$ so that $C = c_E$, then late consumers have nothing to lose by keeping their funds in the bank. That is, for a given late consumer, running to the bank will yield at most c_E which is no larger than the return from government deposit insurance. Thus $\xi = 1$ is sufficient to eliminate runs. QED.

As with other "confidence building measures" in coordination problems, the government insurance is costless in equilibrium. That is, in this model where the only uncertainty is strategic in nature, the impact of the insurance is to resolve the coordination problem and thus eliminate the strategic uncertainty.

Deposit insurance supports a first best allocation.[20] That is, if the government sets $\xi = 1$, the best feasible contract the intermediary can offer is δ^*. Using Proposition 8, there will be no runs and V^* will be obtained.

While deposit insurance has this benefit, it has potentially costly incentive effects which have thus far been ignored. To deal with these important issues, we modify our model to allow for moral hazard by the bank and monitoring by depositors.

First, we introduce another portfolio choice for the bank by assuming that there exists a third technology that yields a second period return of λR with probability ν and 0 otherwise. Assume that $\lambda > 1$ and $\nu\lambda \leq 1$ so that the risky technique has a higher return if it is successful but a lower expected return than the riskless illiquid investment. Thus, the riskless two-period

[20] As Diamond-Dybvig point out, so would the suspension of convertibility given that there is no aggregate uncertainty in π.

investment is preferred to the risky illiquid investment by all risk averters, including depositors.[21]

Suppose that in period 0, the manager of the bank, acting on behalf of risk neutral shareholders who obtain the residual value of the bank in period 2 after all depositors are paid, can choose the bank's investment portfolio. How does the manager evaluate this risky investment? Since shareholders are risk neutral, competition drives expected profits to zero if the riskless illiquid investment is chosen and assuming there is limited liability, the risky investment is preferred since $\lambda > 1$.[22]

The second change to our model is the inclusion of a monitoring decision on the part of depositors. While funds allocated to liquid investments are publicly known, reflecting the uniform quality of buying, say, government debt, the allocation of illiquid investments is not freely observed. Any depositor who monitors incurs a cost K and can force the bank to adopt the promised portfolio.

There is a public goods aspect to monitoring in that a single depositor can influence the entire bank's portfolio, to the benefit of all depositors.[23] As a consequence of this strategic interaction across agents, we characterize the level of monitoring by each agent in a symmetric Nash equilibrium. Since each depositor benefits from the monitoring expenditures, the presence of the information externality will not imply an equilibrium with zero monitoring.

The sequence of events in period 0 is as follows. First, the government sets a deposit

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[21] That is, $\nu U(R\lambda) \leq U(\nu R\lambda) < U(R)$ for any concave $U(\cdot)$.

[22] By limited liability, we simply mean that if the return in investments in period 2 is zero, the shareholders have no liability to depositors. Here the manager/shareholders only value second period goods; they do not face random liquidity needs.

[23] Calomiris-Kahn [1991] model monitoring as a private activity though the outcome of monitoring is made public. The incentives to monitor are created by sequential service in which the agents who monitor are "first in line."

insurance level, ξ. Second, the bank offers a contract, δ, and depositors decide on the allocation of their endowment. Then, each depositor decides whether or not to monitor the bank. If the bank is monitored, then investment decisions are observable to all agents. Finally, the bank manager allocates the funds to the three alternative investments. Our choice of timing here is not very restrictive: the outcome of this model and that with simultaneous moves by the monitor and the banker is the same.

The monitoring decision adds two complications to the model. First, there is the issue of monitoring as a solution to the moral hazard problem. Second, there is the strategic interaction between depositors given the public goods aspect of monitoring.

If there was a single depositor, then monitoring will occur iff

$$(1-\pi)(1-\nu)[U(c_L)-U(\xi c_L)] \geq K. \tag{11}$$

The left-hand side is the expected gain to the depositor from turning the problem into one of full information for a given value of c_L and the right-hand side is the monitoring cost. Note that this condition incorporates the fact that if monitoring did not occur, the bank would invest in the risky technology which would payoff the depositor c_L with probability ν. If ξ is close to 1, then no monitoring by the single agent will occur. In fact, for ξ near 1, there will be no conflict of interest between the depositor and the intermediary: they both prefer to invest in the risky illiquid technique.

The existence of multiple depositors creates a number of interesting complications due to free riding on the monitoring of others. One possibility of resolving this is by cooperative agreement on monitoring: hire an accounting firm as part of the deposit arrangement.

Alternatively, in the non-cooperative game between depositors to determine the level of monitoring by each, there will be asymmetric equilibria in which one depositor monitors and the others free ride. There may also be equilibria in which monitoring costs are shared by a subset of the depositors.

Finally, if (11) holds, then there will also be a mixed strategy equilibrium in the monitoring game in which monitoring occurs for each agent with probability ρ. The symmetric Nash equilibrium level of monitoring, ρ^*, satisfies

$$(1-\rho^*)^{N-1}(1-\nu)[U(c_L)-U(\xi c_L)] = K/(1-\pi). \tag{12}$$

In the equilibrium of the monitoring game between depositors, the expected gains to monitoring, which arise when the individual is a late consumer, others do not monitor and the risky asset fails, is equated to the cost of monitoring. From this, note that, for given c_L, the probability of the bank <u>not</u> being monitored equals $(1-\rho^*)^N$, which is increasing in N, increasing in K and increasing in ν.[24] In equilibrium, there is a chance that the bank will not be monitored regardless of the number of depositors since ρ^* is less than 1 for all N. As expected, ρ^* is a decreasing function of the degree of deposit insurance.

Taken literally, in our simple model, the government could, in fact should, provide deposit insurance for period 1 only. In this way, it can separate the two roles of insurance (protecting against bank runs and low returns on risky investments) and thus avoid any moral hazard problem. This simple solution is rather uninteresting as it reflects the static nature of our

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[24] From (11), we know that $(1-\rho^*)^{N-1}$ is independent of N so that ρ^* must be decreasing in N implying that $(1-\rho^*)^N$ must be increasing in N. That $\rho \neq 0$ despite the public goods nature of the monitoring decision is because the individual investor obtains private gains from monitoring as well. Of course, for K large enough there may be no monitoring in equilibrium even though there are social gains to this activity.

model. In particular, the banking system is not ongoing in the model: there are no new deposits and thus no possibility of runs after period 1.

To make some progress, consider an overlapping generation model in which each generation contracts with an ongoing intermediary. If, as in Freeman [1988], each contract satisfies the resource constraint of (3), the first best contract, δ^*, will be the stationary allocation in this environment.[25] In this economy, in any period, the government cannot distinguish between bank runs caused by pessimistic expectations and insolvency due to moral hazard. The government will then offer the same degree of insurance (ξ) in all periods.

Does deposit insurance support V^* in this environment? Full insurance of deposits ($\xi = 1$) implies that there will be no monitoring on the part of depositors and, as a consequence, the bank will invest in the risky illiquid asset.[26] In fact, the presence of deposit insurance implies that there is no longer a conflict of interest between depositors and the intermediary. In the event of a zero return, the depositors simply collect insurance from the government so that the depositors prefer that the intermediary invests in the risky investment. Due to the pressures of competition this is reflected in the equilibrium levels of c_E and c_L. This, one might argue, corresponds to the commonly told story of current intermediation problems in the U.S. and this is not the first-best allocation, V^*.

If, at the other extreme, there is no deposit insurance and K is not too large, then the allocation will be close to that characterized as δ^* in the previous section of this paper.[27] Of

[25] This approach separates generations, preventing projects financed by one generation from providing consumption for another generation.

[26] Assuming, of course, that government monitoring does not effectively substitute for private monitoring.

[27] The difference between the allocations occurs because, in equilibrium, monitoring does not always occur. Thus there is a small chance of moral hazard and this influences the choice of contract. An explicit characterization of the new contract isn't needed for the discussion which follows.

course, there are runs under that contract which deposit insurance was developed to avoid.

The analysis suggests policies to deal with this tradeoff between monitoring and insurance. As is commonly understood in the principal-agent framework, the need to provide incentives for actions (such as monitoring) and insurance results in the provision of less than perfect insurance to the agent. The reduction in insurance could be accomplished in two ways: either by directly setting $\xi < 1$ (equivalently, by taxing deposit insurance) or by instituting a limit on the insurance.

First, suppose that $\xi < 1$. This will have two important effects. As suggested, from Proposition 8, bank runs will become possible in this economy and this is an important cost of reducing ξ below 1. Note though that even with $\xi < 1$, the provision of government deposit insurance is beneficial in bank run states as a means of redistributing goods to those who were not served. In this manner, the deposit insurance avoids the random rationing of a fixed amount of goods that is implied by the sequential service constraint.

The potential benefits of reducing ξ occur if depositors monitor banks. However, for ξ near 1, there will be no conflict of interest between depositors and intermediaries as both will prefer the risky illiquid investment to the riskless one.[28] Again, this arises because the deposit insurance also provides protection against low returns of the risky investment. Since $\lambda > 1$, ξ near 1 will imply that the risky investment is preferable. Thus, to promote monitoring, the level of ξ will have to be lowered enough to create a conflict between depositors and the

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[28] To see this, consider a simple problem in which an investor wishes to move resources from period 0 to period 1. The intermediary has the choice between a risky and a riskless technique and, given limited liability, prefers the former. In the absence of deposit insurance, the investor prefers that the intermediary invest in the riskless technique and, if necessary, may monitor the intermediary's actions in equilibrium. However, there exists some level of government provided insurance over depositors funds such that both the investor and the intermediary prefer to invest in the risky asset. Thus, the conflict between the desires of the investor and the intermediary exists only for sufficiently low levels of deposit insurance.

intermediaries so that the depositors act on behalf of the government and monitor investment activities.

The second policy, of placing limits on deposit insurance, resembles the system used in the U.S. in which deposit insurance as provided up to $100,000 in each bank. In the context of our model, these caps on insurance coverage are more interesting when there is some heterogeneity across depositors.[29] Suppose that there are low and high income depositors. Then if the deposit insurance fully covers the deposits of low income but not high income agents, the latter might still satisfy (11) and have an incentive to monitor the bank. The insurance will imply that the probability of monitoring will be lower than in the absence of insurance but this probability may still exceed zero. Note too that since the monitoring has a public goods aspect, having the large depositors monitor still provides benefits to the small depositors. Still, bank runs by the large depositors may arise in equilibrium.

There is an important aspect of this policy: the government must effectively commit not to pay deposit insurance to large depositors. Clearly, if the government, ex post, does pay insurance to all depositors and this is anticipated in period 0, there will be no monitoring. In this regard, it is interesting that in a large number of cases, such as Continental Illinois in 1984, the U.S. government did provide deposit insurance to individuals with accounts in excess of the $100,000 cap.[30]

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[29] Here we discuss these implications informally though differences across depositors could be handled within our model quite easily.

[30] The Federal Deposit Insurance Company employs two strategies to deal with failed institutions: deposit payoff and deposit assumption. In the former case, depositors simply receive their funds and the bank is closed. In the latter case, the bank is taken over by another institution and FDIC funds are used to compensate the acquiring bank. In this case, large and small depositors are protected. Since a large fraction of the resolution of bank failures has been through deposit assumption, large depositors have, in effect, received insurance. The FDIC Annual Report provides a more complete explanation and data on the frequency of use of these policies. We are grateful to Warren Weber and Art Rolnick for discussions of this point.

This tradeoff between moral hazard and avoiding bank runs arises because the government has only a single instrument, deposit insurance. Therefore, consider a second instrument: a requirement on the ratio of debt to equity financing for an intermediary. To be precise, suppose that there is an owner/manager of the intermediary who consumes only in period 2. Through government regulation, this agent is required to contribute κ units of the good per unit of illiquid investment to the intermediary's capital account. In this case:

Proposition 9: If $\kappa \geq \kappa^{*} \equiv [\nu(\lambda-1)]/[1-\lambda\nu]$, then the first best allocation is achievable without bank runs.

Proof: Suppose that the government sets $\xi=1$ so that, from Proposition 8, there are no bank runs. With full deposit insurance, there is no costly monitoring by depositors. However, the owner/manager of the bank will choose the safe illiquid investment rather than the risky illiquid investment as long as:

$$R\kappa \geq R\nu[\lambda(\kappa+1)-1] \tag{13}$$

The left side of this inequality is the return to the owner/manager per unit of depositors' resources invested in the safe, illiquid technique. The right side is the return to the owner/manager per unit of depositor's resources invested in the risky illiquid technique, which is positive with probability ν. Both of these returns are net of the funds owed to late consumers. If this inequality holds, which is equivalent to $\kappa \geq \kappa^{*}$, the manager/owner will invest all illiquid funds in the safe technique. The absolute level of required equity capital will equal $\kappa^{*}i^{*}N$, where i^{*} is the first-best level of illiquid investment given implicitly in (4).

QED.

The point of this proposition is that an adequate equity capital base can provide sufficient incentive to owner/managers to overcome the moral hazard problems without the need for monitoring by depositors. In this case, deposit insurance can be provided to prevent bank runs without creating incentive problems.

This solution ignores other potential moral hazard problems arising from conflicts of interest between managers and owners. Further, the solution assumes that enough equity capital exists to support the first-best allocation. In the model, this means that there must exist enough agents without liquidity needs to support intermediation for the remainder of the agents. An unanticipated shock to the equity value of the intermediary could encourage excessive risk taking by managers.

V. Conclusions

The goal of this paper has been to extend the Diamond-Dybvig framework to understand the implications of runs and to evaluate the costs and benefits of deposit insurance. In our model, there is a true liquidity role for intermediaries which provides new conditions for runs and some implications for the response of intermediaries to the possibility of runs. The expected utility from the optimal contract with intermediaries was characterized in Proposition 7 and this provides a benchmark of the best the private sector can provide if runs are possible and there is no deposit insurance.

The paper also analyzed the impact of deposit insurance in this setting. As in Diamond-

Dybvig, there is a clear benefit to the provision of deposit insurance as it prevents runs. The costs are associated with a reduction in the incentives for depositors to monitor and thus riskier investments by intermediaries.

Given the simplicity of our model, we have refrained from characterizing the "optimal" level of deposit insurance. Clearly variations in the level of coverage must tradeoff incentives for insurance and the optimum will depend on the prospects of runs, monitoring costs, the parameters of the risky illiquid investment, etc. At the extremes, the optimal policy is clear. If moral hazard considerations are relatively unimportant (due to a very high probability of success in the risky investment and low monitoring costs), then deposit insurance is desirable to avoid runs. If bank runs are relatively unlikely, then the incentive costs of deposit insurance may outweigh the costs and the private sector, through the variations in allocations described in Propositions 4-6, can adequately deal with the coordination problem.

In the presence of an adequate equity capital requirement, deposit insurance can prevent bank runs without creating moral hazard problems. Potential limitations of this solution arise from the presence of moral hazard between bank owners and managers and difficulties in raising sufficient equity capital. Further, the equity capital requirement must be adjusted in response to changes in the economic environment. These adjustments and the continued monitoring of compliance with this requirement might be costly.

We see the basis for further work on this problem in a number of directions. Historically, interbank loans played an important role in providing a private sector response to the prospect of runs, as described by Chari [1989]; though here that possibility has been ignored. Integrating multiple banks into the framework and then again analyzing the costs and benefits of private and public deposit insurance seems quite important. This exercise may also shed some light on the questions about the different American and Canadian experiences with runs as discussed by Williamson [1989].

A second extension, mentioned a number of times in the text, concerns the lack of true dynamics in the model. The intermediation process is more dynamic than as presented here: there are new depositors and new investments made in each period of time and these flows need to be incorporated into the model.[31] From an empirical perspective, a dynamic model is needed to better understand the time series evidence on the implications of runs for banks' portfolios. One important issue is the liquidity provided by new depositors: will new deposit inflows provide the liquidity to avoid runs? A second issue is the nature of the investment decision of the intermediary. Our preliminary analysis of the problem suggests that, in the absence of aggregate uncertainty, the intermediary can provide liquidity to early consumers without an investment in the liquid asset. Each period, the intermediary distributes the product obtained from the illiquid investment to early consumers of one generation and late consumers of an earlier generation. The interesting aspect of this investment policy is that the intermediary, being less liquid, is more susceptible to runs. A third issue concerns the persistence of runs as part of a dynamic sunspot equilibrium.[32]

Finally, in situations in which the equity capital requirement is insufficient, there are other policies that deserve attention. First, as noted by Diamond-Dybvig and others, in the model without aggregate uncertainty, the suspension of convertibility by intermediaries succeeds

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[31] As noted earlier, our introduction of overlapping generations does not allow for pooling resources across generations.

[32] As in the related work, for example, of Azariadis [1981] and Azariadis-Guesnerie [1986].

in avoiding runs. In the presence of aggregate uncertainty, Diamond-Dybvig argue that deposit insurance dominates the suspension of convertibility. A ranking of these policies in the presence of moral hazard is an important topic to consider. Even in the context of deposit insurance, we have not yet evaluated important policies such as conditioning the insurance premia paid by intermediaries on a measure of portfolio risk.[33]

[33] Kareken-Wallace [1978] discuss a wide-range of regulations that could be analyzed in this model.

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