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BANK RUNS: DEPOSIT INSURANCE AND CAPITAL REQUIREMENTS*

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Diamond and Dybvig provide a model of intermediation in which deposit insurance can avoid socially undesirable bank runs. We extend the Diamond-Dybvig model to evaluate the costs and benefits of deposit insurance in the presence of moral hazard by banks and monitoring by depositors. We find that complete deposit insurance alone will not support the first-best outcome: depositors will not have adequate incentives for monitoring and banks will invest in excessively risky projects. However, an additional capital requirement for banks can restore the first-best allocation.

1. INTRODUCTION

The publicly supported deposit insurance plans of a number of countries, most notably the United States and Canada, have recently come under intense public scrutiny as concerns have mounted about the substantial contingent liabilities they have created for taxpayers. In the United States the savings and loan (S&L) crisis led to the transfer of a huge amount of bad debt, estimated recently at about $130 billion, onto taxpayers' shoulders.2 Created originally to support the banking sector by building depositor confidence, there is recognition that the insurance provided by

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2 There is a considerable literature on the S&L crisis; see, for example, Feldstein (1991), Kormendi et al. (1989), and White (1991).
these plans has encouraged excessive risk taking by financial intermediaries. These concerns have led to calls for the reform of deposit insurance and even suggestions that it be abolished.

This paper attempts to evaluate the trade-offs between risk sharing and moral hazard associated with the design of banking regulations. In particular, we focus on two policy instruments: deposit insurance and bank capital requirements. We are interested in how these instruments can be used (and misused) to control bank runs in an environment in which banks can make imprudent investments and depositors can monitor bank behavior.

Reflecting ongoing problems in the financial services sector, there has been a great deal of research recently on lending behavior, bank stability, and optimal banking regulation. While a number of publications have considered parts of the problem addressed here, no individual contribution tackles the joint determination of optimal deposit insurance and capital requirements within a bank runs model with risk-averse depositors, depositor monitoring, and moral hazard. Given the ongoing public debate over deposit insurance and capital requirements and the attention paid to the supposed trade-off between bank runs and moral hazard, a structure is needed that contains these elements.

With its emphasis on bank runs, the model of Diamond and Dybvig (1983) provides a convenient starting point for studying these issues. In the absence of any moral hazard considerations, Diamond and Dybvig argue that publicly provided deposit insurance can be effective as protection against expectations-driven bank runs. However, their

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3 Deposit insurance was created in the United States during the Great Depression (1934) to restore depositor confidence. It came to Canada in 1967. Concerns about the Canadian system are expressed in Smith and White (1988).

4 Some of this literature is reviewed in the recent books by Dewatripont and Tirole (1994) and Freixas and Rochet (1997). The articles closest in purpose to this one include Giammarino et al. (1993), Matutes and Vives (1996), Besanko and Kanatas (1993), Holmstrom and Tirole (1993), Kupiec and O’Brien (1997), and Peck and Shell (1999). Each considers some aspect of our problem, but none combines the elements we view as important here. For example, Giammarino et al. (1993) consider optimal deposit insurance premia in markets with bank moral hazard but no bank runs. Matutes and Vives (1996) study the effect of competition on bank fragility with deposit insurance. Besanko and Kanatas (1993) consider the provision of funds to firms from both banks (through loans) and capital markets in a model with bank moral hazard but no bank runs. Studying bank lending behavior (without deposits or bank runs), Holmstrom and Tirole (1993) find that borrower moral hazard can be controlled by requiring that borrowers contribute some of their own funds—a requirement not unlike the capital requirements that banks face. Finally, Peck and Shell (1999) also examine policies that might influence the probability of bank runs, but focus on deposit contracts that permit the suspension of convertibility and on government restrictions on banks’ portfolios of loans.

5 Further, Wallace (1988) has argued that there is an inconsistency in the Diamond-Dybvig model’s treatment of deposit insurance. The spatial separation that motivates banking appears inconsistent with the ability of governments to provide deposit insurance. However, Wallace goes on to point out that “...this argument does not say that any kind of deposit insurance is infeasible. It only says that the policy that Diamond and Dybvig identify with deposit insurance is infeasible...” (p. 13). We are in complete agreement; clearly the financing of deposit insurance must be credible to eliminate certain equilibria. Therefore, in contrast to Diamond and Dybvig, we rely on the presence of an outside group of agents (“taxpayers”) as a tax base. Essentially, the government has enough information to tax labor income without needing to overcome any spatial separation constraints.
model does not incorporate the moral hazard considerations seen to be central to recent policy debates. Deposit insurance avoids bank runs but has adverse incentive effects: it implies less monitoring by depositors, which allows banks to hold riskier portfolios. In fact, if deposit insurance is complete enough, depositors’ and banks’ interests are aligned: both types of agents are eager to hold high-risk portfolios, effectively gambling with taxpayers’ money. Thus a trade-off emerges between providing insurance against bank runs and monitoring incentives.

By characterizing this trade-off, our model permits a derivation of the optimal degree of deposit insurance. In general, deposit insurance with depositor monitoring is not sufficient to support the first-best outcome. However, appropriately designed capital requirements can eliminate the incentive problem caused by deposit insurance and support the first-best allocation.

From the perspective of our model, the experience in the U.S. during the 1980s suggests two forms of regulatory failure. First, capital requirements were inadequate. Second, the relaxation of Regulation Q allowed banks to more aggressively compete for deposits, which, along with deposit insurance, led to excessively risky investment. This is certainly not a novel story but one that appears here in a consistent, formal framework.

2. MODEL

The model is a modified version of Diamond–Dybvig (1983). There are \( N \), ex ante identical, agents in the economy who are each born with a unit endowment, which they deposit with an intermediary in period 0. At the start of period 1, agents are informed about their taste types. A fraction \( \pi \) learn that they obtain utility from period 1 consumption only (early consumers), while the others obtain utility exclusively from period 2 consumption (late consumers). As in the first part of Diamond and Dybvig (1983), assume that \( \pi \) is nonstochastic and known to all agents. Denote by \( c_E \) and \( c_L \) the consumption levels for early and late consumers, respectively, and let \( U(c) \) represent their utility function over consumption. Assume that \( U(\cdot) \) is strictly increasing and strictly concave, \( U'(0) = \infty \), and \( U(0) = 0 \).

There are two technologies available for transferring resources over time. First, there is a productive technology that is not completely liquid. This technology provides a means of shifting resources from period 0 to 2, with a return of \( R > 1 \) over the two periods. However, liquidation of projects using this technique yields only one unit in period 1 per unit of period 0 investment. Second, there is a storage technology, available to both intermediaries and consumers, that yields one unit in

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6 In Cooper and Ross (1998) we allow consumers to make their own investments rather than using an intermediary and prove that using an intermediary in this structure always weakly dominates autarky.

7 In the last part of their article they consider the importance of aggregate uncertainty to argue further in favor of deposit insurance instead of policies that suspend convertibility.
period \( t + 1 \) per unit of period \( t \) investment, \( t = 0, 1 \). While not as productive as the illiquid technology over two periods, storage provides the same one-period return.\(^8\)

The intermediary operates in a competitive environment, which compels it to offer contracts that maximize consumers’ \( \text{ex ante} \) expected utility subject to a break-even constraint. If the \( \text{ex post} \) consumer taste types were costlessly verifiable it would therefore offer a contract \( \delta^* = (c^*_E, c^*_L) \) solving

\[
\max_{c^*_E, c^*_L} \pi U(c^*_E) + (1 - \pi) U(c^*_L)
\]

\[
s.t. \quad 1 = \pi c^*_E + \frac{(1 - \pi) c^*_L}{R}
\]

From the first-order conditions, the optimal contract satisfies

\[
U'(c^*_E) = RU'(c^*_L)
\]

Since \( R > 1 \), the strict concavity of \( U(\cdot) \) implies that \( c^*_E < c^*_L \) for (2) to hold.

Diamond and Dybvig establish that when consumer tastes are private information, multiple equilibria may exist. The contracting problem can be formulated with three stages. First, the contract is set by the intermediary, which specifies a consumption level for each type of consumer \( \text{independent} \) of the number of consumers claiming to be each type.\(^9\) Second, agents learn their preferences and these are announced to the intermediary. Finally, the allocation of goods to agents is determined by the contract.

The first-best outcome with the contract \( \delta^* \) will be one equilibrium of this game. Truth telling is a dominant strategy for early consumers while truth telling by late consumers is a best response to truth telling by all other late consumers.

Under \( \delta^* \) there may also exist an equilibrium in which all late consumers misrepresent their tastes and announce that they are early consumers. This can be an equilibrium if the intermediary does not have sufficient resources (including liquidated illiquid investments) to provide \( c^*_E \) to all agents. As in the Diamond–Dybvig model, the late consumers who do not withdraw in period 1 obtain a \textit{pro rata} share of the bank’s period 2 assets. This equilibrium with misrepresentation is termed a “bank run.”

The first-best allocation is vulnerable to runs iff \( c^*_E > 1 \): otherwise, the intermediary would have sufficient resources to meet the demand of \( c^*_E \) by all agents in period 1. Diamond and Dybvig (1983) show that if agents are sufficiently risk averse, then \( c^*_E \) will exceed 1.

\(^8\) In this setup, which comes from Diamond and Dybvig, returns on investments made in this productive technology are always (weakly) greater than those in the alternative (storage). In Cooper and Ross (1998) we extend the model by adding a liquidation cost to these illiquid projects that renders the one-period return to liquidated investments less than the alternative. This expands the set of conditions under which bank runs can occur and influences agents’ investment and contract choices. It does not, however, have implications for the results described below so we have chosen to work with the simpler model here.

\(^9\) Thus, in particular, it is not feasible for the bank to accumulate information about withdrawals and make payments to depositors contingent on this information. Further, agents are unable to meet at a common location after period 0, thus eliminating the types of \( \text{ex post} \) markets considered in, for example, Jacklin (1987).
As described in Alonso (1996) and Cooper and Ross (1991, 1998), there are essentially two ways the intermediary can optimally respond to the possibility of multiple equilibria. One is to find the best contract available that is not vulnerable to runs. This best runs-preventing contract comes from solving (1) with the added constraint $c_E \leq 1$ so that there are always sufficient resources available in period 1 to pay all consumers. Concavity arguments demonstrate that if the first-best contract is vulnerable to runs (i.e., $c_E > 1$), the best runs-preventing contract will involve $c_E = 1$ and $c_L = R$.

As an alternative, 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. Instead of preventing runs, the intermediary adjusts the contract to reduce the impact of runs in the event they arise.

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 the pessimism leads to a bank run. With probability $(1 - q)$, there is optimism and no run occurs. In this way, the beliefs of depositors are tied to a move of nature that determines their actions. The intermediary recognizes this dependence in designing the optimal contract.

Taking the probability of liquidation, $q$, as given, the contract solves (assuming $c_E > 1$)

\[
\max_{c_E, c_L} \left( 1 - q \right) \left[ \pi U(c_E) + (1 - \pi) U(c_L) \right] + q U(c_E)(1/c_E)
\]

s.t. \[1 = \pi c_E + \frac{(1 - \pi)c_L}{R}\]

Let $\delta(q)$ be the contract solving this problem. Cooper and Ross (1998) show the existence of a critical $q^* \in (0, 1)$ such that the best runs-preventing contract dominates the best contract with runs if $q > q^*$ and the reverse holds if $q < q^*$.

3. SUPPORTING THE FIRST-BEST: DEPOSIT INSURANCE AND CAPITAL REQUIREMENTS

The previous section characterizes the optimal response of a private bank facing the prospect of a run. Regardless of whether the intermediary optimally adopts a runs-preventing contract or allows runs, the possibility of bank runs clearly lowers expected utility below that attainable in the first-best solution. This naturally raises

\[10\] Bental et al. (1990) and Freeman (1988) also adopt a sunspots approach. In contrast to our work, those articles 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.

\[11\] Here an agent receives $c_E$ with probability $1/c_E$ in the event of a run, which occurs with probability $q$. Note that if the solution to (3) involved $c_E \leq 1$ it would in fact be runs-preventing and therefore be dominated by the best runs-preventing contract ($c_E = 1$ and $c_L = R$).
the question of whether some government intervention in the form of deposit insurance or other instrument could prevent runs and thus improve welfare.  

Deposit insurance is a contract set by the government that provides a payment to depositors in the event that the bank is unable to meet its obligations. Diamond and Dybvig argue that a simple deposit insurance scheme will eliminate bank runs in their model. However, their argument leaves aside the adverse incentive effects of deposit insurance on both the investment strategy of the intermediary and the monitoring decisions of depositors. We study this by adding both moral hazard and monitoring by depositors to our model. Our main result in this section is that an appropriately designed capital requirement coupled with deposit insurance can avoid bank runs without creating severe moral hazard problems.

3.1. Extended Model. We modify the basic model in a number of ways, detailed in the subsections that follow. First, we introduce a richer investment choice for the banks. Second, we allow for a monitoring decision by depositors. Third, we introduce both deposit insurance and capital requirements as policy instruments for the government.

The sequence of events in period 0 is as follows: First, the government sets a deposit insurance policy. In general, the government contract stipulates payments to early and late consumers as a function of the deposit contract in the event the intermediary is unable to make its promised payments. We denote the payments to early and late consumers as $I(c_E)$ and $I(c_L)$ respectively. Since the government is unable to observe the types of private agents, it too must rely on the agents’ announcements. Put differently, those agents who appear at the intermediary in period 1 are termed early consumers and are eligible for the government insurance over $c_E$ in the event the intermediary is unable to meet its obligations. Likewise, an agent who makes the announcement of being a late consumer is eligible for government insurance over $c_L$ if the bank fails in period 2. Importantly, if a bank fails in period 1, then late consumers will not receive insurance over $c_L$. Instead, they will receive the same payment as early consumers if a bank fails in period 1. Note that we assume that government insurance policy depends on the deposit contract offered by the intermediary.

Second, the competitive banks offer a contract, $\delta$. Depositors then decide on the allocation of their endowment and whether to monitor the bank. If the bank

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12 For the purposes of this exercise, we do not consider private deposit insurance schemes.
13 For simplicity, assume that the tax obligations to finance deposit insurance fall upon agents who are not depositors. Hence 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. Here we imagine a government policy that provides deposit insurance to agents 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. We assume that the social welfare function is such that providing this insurance is desirable. 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.
DEPOSIT INSURANCE AND INCENTIVES

is monitored, investment decisions are observable to all agents. The depositors then learn their taste types. Finally, the bank manager allocates the funds to the two investments. Our choice of timing here is not very restrictive: the outcome of this model and that with simultaneous moves by the monitor(s) and the banker are the same though it is important that the monitoring occurs before the types are realized.

3.1.1. Richer technology. To allow the bank an avenue for moral hazard, assume that there exists a second, multiperiod technology that yields a second period return of $\lambda R$ with probability $v$ and 0 otherwise. Further, assume that $\lambda > 1$ and $v \lambda \leq 1$ so that this 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 investment is preferred to the risky illiquid investment by all risk averters. As with the riskless illiquid technology, this alternative technology also yields one unit in period 1 per unit invested in period 0.

The bank’s investment policy is chosen by a risk-neutral manager who represents the bank’s owners (shareholders). We assume that any funds remaining after the payment of $c_L$ to the late consumers are retained by the shareholders of the bank. As before, if the intermediary does not have sufficient funds for the late consumers, then these agents (and not the shareholders) have rights to a pro rata share of the bank’s resources.

As we shall see, under some contracts, the manager may have an incentive to invest using the risky technology. In particular, in the absence of a minimum capital requirement, the risky investment is preferred by the manager since $\lambda > 1$ gives him (i.e., the shareholders) a chance at a high return. When deposit insurance is sufficiently generous, depositors will not care that the bank undertakes risky investments.

More formally, suppose that the bank offered depositors the first-best contract $\delta'$ and that the government provides depositors with complete deposit insurance; i.e., $I(c_L) = c_L$. Let $i$ denote the amount of resources (per unit of deposit) that the intermediary places in the risky illiquid investment. Then $i$ is chosen to

$$\max_{i} \left[ v (i \lambda R + (1 - i - \pi c^*_L) R - (1 - \pi) c^*_L) + (1 - v) \max(1 - i - \pi c^*_L) R - (1 - \pi) c^*_L, 0) \right]$$

The max operator appears here since the bank may not have enough resources to meet the needs of depositors when the risky investment fails. Since the intermediary earns zero profits in the first-best contract when it invests all of its funds in the riskless illiquid technology, for any $i > 0$, the intermediary has zero return in the state in which the risky investment fails. Further, with $v \lambda \leq 1$, the intermediary’s expected return is positive and increasing in $i$. Thus the solution is for the intermediary to place all funds in the risky illiquid investment. Since

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14 That is, $vU(R\lambda) + (1 - v)U(0) \leq U(vR\lambda) < U(R)$ for any concave $U(\cdot)$.

15 For example, if a bank’s liabilities are deposits insured with fixed-rate Federal Deposit Insurance Corporation (FDIC) insurance, it is well known that the bank may have an incentive to select very risky assets since the deposit insurers bear the brunt of downside risk but the bank owners get the benefit of the upside risk” (Diamond and Dybvig, 1986, p. 59).
3.1.2. Depositor monitoring. The second change to our model is the inclusion of a monitoring decision on the part of depositors. Any depositor who monitors incurs a cost $\Gamma$ (modeled as a utility loss) and can force the bank to adopt the depositor’s desired portfolio.\textsuperscript{16} Given the moral hazard problem outlined above, depositor monitoring is a potentially important element in overcoming the incentive of banks to invest in risky ventures.

We begin the analysis by studying the monitoring decisions by the depositors given the investment choices by the manager, the level of deposit insurance provided by the government, and a deposit contract, $(c_E, c_L)$. We consider here the case of a single depositor, but the qualitative results can be extended to the multidepositor case.\textsuperscript{17} If the bank has an incentive to invest in the risky technique, then monitoring will occur iff

\begin{equation}
(1 - \pi)(1 - v)(1 - q)[U(c_L) - U(I(c_L))] \geq \Gamma
\end{equation}

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 assertion that if monitoring did not occur, the bank would invest in the risky technology that would yield the depositor $c_L$ with probability $v$. Further, as the monitoring decision is made in period 0, the individual values the information only if he is a late consumer, which happens with probability $(1 - \pi)$. Finally, the gains to monitoring are lost if there is a bank run since both the risky and riskless illiquid techniques generate equal returns over the first period. So, the left-hand side of (4) includes $(1 - q)$, the probability of optimism.

The influence of deposit insurance on monitoring is apparent from this condition. If $I(c_L)$ is close to $c_L$ for all levels of late consumption, then the single agent has no incentive to monitor. However, for small levels of insurance, monitoring will take place. For this analysis, we assume that when there is no deposit insurance, a single depositor will monitor if $c_L = c'_L$.

\textsuperscript{16} Calomiris and 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.” Our results are robust to assuming that the information generated by monitoring is private.

\textsuperscript{17} 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 via a cooperative agreement on monitoring: an accounting firm is retained as part of the deposit arrangement. Alternatively, in the noncooperative 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, there may also be a mixed-strategy equilibrium that each agent monitors with some probability. Such a model is considered in an expanded version of this article available from the authors.
3.2. **Capital Requirements.** Consider a second instrument of government policy: a requirement on the ratio of debt to equity financing for an intermediary. To be precise, suppose that the shareholders of the intermediary are required by the government to contribute $\kappa$ units of the numeraire good per unit of deposit to the intermediary’s capital account.

Let $i$ again denote the funds (per unit of deposit) that the intermediary places in the risky investment. Then the portfolio choice of the intermediary is determined from

$$
(5) \quad \max_i [v(iR + ((\kappa + 1) - i - \pi c_L)R - (1 - \pi)c_L) \\
+ (1 - v) \max((1 + \kappa - i - \pi c_L)R - (1 - \pi)c_L, 0)]
$$

The first part of this expression applies to the case of a successful risky investment outcome, in which case the shareholders of the bank earn a high return of $iR$ on the $i$ units placed into the risky illiquid investment. With probability $(1 - v)$, however, the risky investment fails and the bank’s resources are limited to $(1 + \kappa - i - \pi c_L)$, which earns a return of $R$. These funds are then used to meet the demands of late consumers, given by $(1 - \pi)c_L$. It is possible that the intermediary does not have sufficient resources to meet these demands by late consumers so that the bank’s shareholders obtain $0$. Hence the max operator in (5).

In fact, the nonlinearity created by the possibility of bankruptcy is central to the moral hazard problem faced by a bank. In particular, suppose that the terms of the contract offered depositors are such that there exists a level of risky illiquid investment ($i'$) satisfying

$$
(1 + \kappa - i' - \pi c_L)R = (1 - \pi)c_L
$$

At this critical level of risky investment, the firm has zero profits in the second period when the risky project fails. It is easy to see that the expected payoff of the intermediary is higher at $i = 0$ than for any $i \in (0, i')$ since shareholders bear all of the downside risk from investing more resources in the risky illiquid project for $i$ in this interval. For any $i \geq i'$, shareholders do not bear the risk of this investment, so it is profitable to put more funds in the risky investment. Thus, from this optimization problem, the choice of the intermediary is reduced to placing either all of the funds in the risky investment or all of the funds in the riskless investment.

3.3. **Supporting the First-Best Allocation.** The point of the following proposition is that if the capital requirement is sufficiently large, shareholders will no longer prefer to gamble with depositors’ funds and thus the moral hazard problem is solved. Further, with complete deposit insurance, bank runs are eliminated. Finally, depositors will have no need to monitor the bank since they are completely insured.
Formally:

**Proposition 1.** If \( I(c_L) = c_L \) for \( c_L \leq c_L^* \), \( I(c_L) = c_L^* \) for \( c_L > c_L^* \), \( I(c_E) = c_E \) for \( c_E \leq c_E^* \), \( I(c_E) = c_E^* \) for \( c_E > c_E^* \), and \( \kappa \geq \kappa' \equiv \frac{v(\lambda - 1)}{1 - \lambda v} \), then the first-best allocation of \((c_E, c_L)\) is achievable without bank runs and without monitoring.

**Proof.** Since deposit insurance is complete up to \((c^*_E, c_L^*)\), if the first-best contract is offered, bank runs will be eliminated.

Using the first-best contract, (5) becomes

\[
\max_i \left[ v(i^* R + ((K + 1) - i - \pi c_E^*)R - (1 - \pi)c^*_L) + (1 - v) \max((1 + K - i - \pi c_E^*)R - (1 - \pi)c^*_L, 0) \right]
\]

Using the resource constraint of \( R = (1 - \pi)c^*_L + R\pi c_E^* \), this reduces to

\[
\max_i \left[ v(i^* R + (K - i)R) + (1 - v) \max((K - i)R, 0) \right]
\]

Clearly, \( i \) will be set to 0 or to its maximal value of \((1 + \kappa)\) since any interior choice of \( i \) is dominated by one of these extremes. The profits of the intermediary are higher at \( i = 0 \) than at \( i = 1 + \kappa \) iff

\[
RK > v(1 + \kappa)\lambda R - Rv
\]

which reduces to the condition given in the proposition.

Finally, from the definition of the first-best, there is no other contract that can increase the expected utility of the consumer. Thus, if capital requirements meet the bound given in the proposition, banks will offer the first-best contract to depositors and will not have any incentive to invest in the risky technology. Depositors will therefore have no incentive to monitor and, given the presence of complete deposit insurance, there will be no bank runs.

The point of this proposition is that an adequate equity capital base can provide sufficient incentive to owners managers to overcome the moral hazard problems without the need for monitoring by depositors. In this case, deposit insurance can prevent bank runs without creating incentive problems and the first-best allocation, given as the solution to (2), can be supported.\(^{18}\)

Note that the capital requirement does not specify how the intermediary must invest the funds that shareholders provide. In the proof of Proposition 1, we find that if the intermediary has an incentive to invest depositors’ funds in the risky illiquid technology (which occurs iff \( \kappa < \kappa' \)), then the intermediary will invest shareholders’ funds in the risky venture as well. If it did not do so, the intermediary would be forced to pay depositors all of the shareholders’ funds in the event that the risky venture failed. Hence the incentive to gamble with depositors’ funds will spill over to the allocation of shareholders’ funds as well.

\(^{18}\) As a referee has correctly pointed out, the assumption of risk neutrality on the part of the bank is important to this result. If the bank manager and shareholders were risk averse, there would be additional costs associated with investing own-capital in a bank with uncertain returns.
The effects of parameter changes on the critical level of capital $K^*$ are of interest. For example, a mean-preserving spread on the returns from the risky asset, as represented by a combination of increasing $\lambda$ and decreasing $\nu$ that leaves $\lambda \nu$ constant, will increase $K^*$. That is, as the probability of the risky asset succeeding falls, holding the expected return constant, more capital will be needed to deter morally hazardous investment behavior. This is a fairly intuitive result. However, if we increase either $\lambda$ or $\nu$ while holding the other fixed—in either case increasing the efficiency of the risky investment—the minimum capital requirement actually rises. As the risky asset is more attractive, we need to impose tighter minimum capital requirements.

4. THE SAVINGS AND LOAN CRISIS

The model developed here is also useful in understanding the role that sub-optimal regulatory policies played in the S&L crisis in the United States in the 1980s. This crisis, almost certainly one of the most important events in American banking history, has imposed costs on taxpayers that continue to mount.

In the late 1970s and early 1980s interest rates climbed substantially, and S&Ls and some banks were squeezed as depositors withdrew funds to put them into higher-yielding Treasury Bills and money market funds while the long-term mortgages that provided much of the S&L income were fixed at interest rates far below market rates. Regulatory reforms introduced to help S&Ls compete (e.g., flexible rate mortgages), the relaxation of controls on interest rates paid (Regulation Q), and the expansion of deposit insurance protection combined with a lack of regulatory oversight to introduce severe problems of moral hazard. Thrifts with low levels of net worth now had the opportunity to gamble with other people’s (i.e., taxpayers’) money and insured depositors had little incentive to monitor their thrifts. Indeed, if taxpayers were going to cover the downside, depositors shared the thrift owners’ interest in risky investments with high upside potential, even if the expected yield was low. For a time, this strategy led to rapid growth of S&Ls, but eventually the poor quality of their investments brought many down.

To see how our model can explain important aspects of the S&L crisis, we focus on two key aspects of White’s (1991) description of the S&L crisis: (i) the removal of Regulation Q and (ii) the inadequacy of capital requirements. Removing Regulation Q allowed banks more flexibility in competing for depositors, that is, greater latitude in setting $c_E$ and $c_L$. One view of Regulation Q was that it essentially mandated runs-preventing contracts, and its repeal allowed banks to offer contracts that were vulnerable to runs. When squeezed by the new pressure to offer higher interest rates to attract deposits even while many of their loans (often mortgages) were set at very low rates, many smaller institutions became seriously undercapitalized—a deficiency not

19 For background on the crisis and its causes, see, for example, White (1991), Grossman (1992), and Dewatripont and Tirole (1994, Chapter 4).
always noticed by regulators failing to measure the values of assets at current market prices.\(^{20}\)

While the inadequate capitalization may have changed the incentives of banks to avoid risky projects, the existence of deposit insurance implied that depositors were still willing to place funds in these institutions. It is important to recognize that, in our model, deposit insurance does not create the moral hazard problem: the manager’s interest in the risky asset would exist in the absence of insurance. What the deposit insurance does is reduce the incentive of depositors to monitor banks. In the case of many of the failed S&Ls, the interests of these agents became aligned with those of the banks and jointly they gambled with taxpayers’ money.\(^{21}\)

To formalize this point, we consider the implications of suboptimal deposit insurance and inadequate capital requirements. In particular, we assume that no capital requirements are in place. This assumption simplifies the analysis and captures the theme that a key aspect of this experience was inadequate capital requirements. While outside our model, one could imagine that a period of deflation led to a reduction in the value of capital and thus the inadequacy of existing capital requirements.\(^{22}\) Further, we consider a relatively simple deposit insurance scheme, in which the government provides a fraction \(c\) of the resources owed to depositors (both early and/or late types) when a bank fails.\(^{23}\) In particular, recall that we assume that if a bank fails in period 1, both early and late consumers receive a fraction of \(c_E\). Essentially, the government insures current deposits rather than promised payments.

While admittedly quite crude, this configuration of policy choices and market conditions matches the description of the savings and loan industry in the 1980s provided by White (1991). Consider first the extent of deposit insurance coverage in the United States. Note that partial insurance is ostensibly a component of U.S. policy through limits on coverage. However, it is well understood 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

\(^{20}\) White (1991) admits that the regulators had a very difficult job in this new environment and that they even suffered from some very bad luck. For example, a key Texas office was moved at just the wrong time—disrupting the work of regulators just when their oversight was needed the most.

\(^{21}\) In related research, Grossman (1992) studies the risk-taking behavior of insured and uninsured thrift institutions in Milwaukee and Chicago during the 1930s. He finds evidence of moral hazard in that after a few years of deposit insurance coverage, thrifts would move toward holding riskier portfolios. He also finds that the level of regulatory oversight influenced the degree of risk taking. Federally insured thrifts were the most heavily regulated and took on less risk than their state-chartered counterparts. And the stricter regulation in Wisconsin led thrifts in that state to build less risky portfolios than those of state-chartered thrifts in Illinois, where the regulations were less stringent.

\(^{22}\) Mechanisms such as this, where deflation leads to incentive problems, are often discussed in the literature on financial frictions.

\(^{23}\) By assumption, the deposit insurance covers the same fraction of early and late consumption. Hence, more sophisticated policies that might prevent runs without creating a moral hazard problem by insuring early consumption only are not considered.
$100,000 cap.\textsuperscript{24} Diamond and Dybvig (1986) suggest that since the government did not credibly commit \textit{ex ante} to pay off all depositors (which might have protected the bank from the capital flight it experienced) but then covered those losses \textit{ex post}, "they incurred the expense of deposit insurance without the benefits" (p. 64).

With regard to capital requirements, the losses suffered by many S&Ls had effectively reduced their capital to levels so low that shareholders had relatively little to lose from making high-risk investments. With these investments, they were essentially gambling with taxpayers' money. Hence it is of interest to determine the model's predictions under this scenario, to see if we have a structure that can explain what actually happened.

There is an obvious concern associated with this characterization of deposit insurance: taking $\alpha$ as given, an intermediary has the incentive to make outrageous promises to depositors, given that the government is insuring these offers. While the removal of Regulation Q certainly gave the intermediaries more latitude, some constraint on the choice of $\delta = (c_E, c_L)$ must be imposed. In our analysis, we assume that the government will provide insurance iff the terms of $\delta$ solve the contracting problem given the level of deposit insurance and under the presumption that the bank will not invest in the risky illiquid technology. Given that the environment is public information, there is no reason for the government to insure contracts that are only reasonable if the bank commits moral hazard and invests in risky projects. As a consequence, the bank is unable to pass along gains from excessive risk taking to depositors.\textsuperscript{25}

To make the role of monitoring clear, we make use of (4) and assume that there is effectively only a single agent who can either monitor the bank or not. Since the cost of monitoring has been assumed to take the form of a utility loss, the contracting problems specified above do not change as we vary the cost of monitoring.

Further, following Proposition 1, the bank chooses to invest funds in either the risky illiquid investment project or the riskless illiquid investment project.

\textsuperscript{24} 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.

\textsuperscript{25} One could add an element of unobservable side payments from the bank to depositors into the model to allow the sharing of these gains. As discussed below, this would certainly influence the characterization of the critical value of deposit insurance in Proposition 2 but not change the results qualitatively. An alternative approach that would permit some of the gains from this risk taking to be passed on to depositors would allow the bank to offer depositors contracts that it would have the resources to fully honor only if the risky investment was successful. That is, suppose regulators could not observe $v$ and believed the bank's claim that $v = 1$. In this case with full deposit insurance the bank can—indeed competition will force it to—provide more generous deposit contracts knowing that the deposit insurer will certainly be needed if the risky project fails. So again we have the depositors and shareholders both wanting to invest in the risky, inefficient project.
This discrete choice highlights the moral hazard problem for the bank and its depositors.

Finally, we assume that \( q \) is sufficiently small so that the contract with runs dominates the runs-preventing contract in the absence of deposit insurance. Hence, when we characterize the optimal contract in the presence of deposit insurance, the assumption that \( q \) is small implies that the private sector will not adopt runs-preventing contracts. We comment below on the robustness of our results to the alternative assumption that \( q \) is large enough to warrant the adoption of runs-preventing contracts, at least for some levels of deposit insurance.

With complete deposit insurance \((x = 1)\), the intermediary will prefer to invest in the risky illiquid technology and depositors will not care since, in effect, they are gambling with other agents’ money. At the other extreme of no deposit insurance \((x = 0)\), there is no moral hazard problem if monitoring costs are low enough so that depositors monitor the intermediary and thus force the intermediary to invest in the riskless illiquid technique. From this, it is not surprising that there exists a critical level of deposit insurance, denoted \( x' \), at which depositors are indifferent between investment in the risky and riskless ventures. This leads to the following characterization of the optimal level of deposit insurance, \( x^* \).

**Proposition 2.** The optimal level of deposit insurance will be at one of two levels, \( x^* \in \{x', 1\} \).

**Proof.** To understand the possibility of \( x^* = x' \), consider first the design of the best contract allowing for runs in the presence of deposit insurance assuming that the intermediary uses the riskless illiquid technique. This is (3) modified to include deposit insurance, i.e.,

\[
\max_{c_E, c_L} \left( 1 - q \right) \left[ \pi U(c_E) + (1 - \pi) U(c_L) \right] + q \left[ U(c_E) \left( \frac{1}{c_E} \right) + U(xc_E) \left( \frac{c_E - 1}{c_E} \right) \right]
\]

s.t. \( (1 - \pi)c_L = R(1 - \pi c_E) \)

Let \( \delta(x) = (c_E(x), c_L(x)) \) denote the solution to this contracting problem.

Now consider the optimal contract allowing for runs in the presence of deposit insurance assuming that the intermediary uses the risky illiquid technique. This is clearly preferred by the intermediary, given that its shareholders benefit when the risky project succeeds and bear no risk if it fails. Put differently, with no capital requirement, the bank will have an incentive to invest in the risky technique.

Will the depositors monitor? Given \( \delta(x) \) and the assumption of a single monitor, (4) becomes

\[
(1 - \pi)(1 - v)(1 - q) \left[ U(c_L(x)) - U(x(c_L(x))) \right] \geq \Gamma
\]

Let \( x' \) be the level of deposit insurance such that (9) holds as an equality. We assume that \( \Gamma \) is small enough so that monitoring will occur at \( x = 0 \) but not for \( x \) near 1. So by continuity of \( U(\cdot) \) and hence continuity of the solution to (8), \( x' \in (0, 1) \). In sum, if the government sets the level of deposit insurance at \( x' \), it would anticipate...
that the optimal contract would solve (8) and the depositor would be indifferent between monitoring and not monitoring.

At \( z = 1 \), there will be no bank runs and no monitoring. Hence, investment will be in the risky illiquid investment.

It is straightforward to see that only two values of deposit insurance are relevant. For values of \( z \in [0, z'] \), there is no moral hazard as the bank is always monitored. Starting at \( z = 0 \), increases in \( z \) would just change the level of insurance given to depositors. As the best contract does not eliminate runs, this insurance may have social value. For values of \( z \in (z', 1) \), there is a moral hazard problem but there are no additional incentive problems created by increasing the level of deposit insurance from \( z' \) toward 1. Hence, it is sufficient to compare social welfare at \( z' \) with that at 1.

Intuitively, the reduction of the optimal deposit insurance rate to the two possible outcomes reflects the trade-off between insurance and moral hazard. For \( z \leq z' \), consumers monitor and prevent the risky venture. At \( z = z' \), the incentives change and for \( z > z' \), depositors are unwilling to monitor and thus intermediaries choose risky illiquid investments. Thus, a key aspect of the proof concerns the existence of \( z' \).

Thus, with inadequate capital requirements, the government is forced to choose between the insurance gains from deposit insurance and its adverse incentive effects. In our model, this trade-off is reflected in the choice between \( z' = 1 \) and \( z' = z' \). By continuity, if \( q \) is sufficiently close to zero so that the prospect of runs is infinitesimal, then the best policy is to adopt partial deposit insurance and thus avoid bank moral hazard problems. Alternatively, if the moral hazard problem is itself small, say because \( \psi \lambda \) is near 1, then it is best to offer full deposit insurance.

Regardless of whether deposit insurance is full or partial, it is important to note that the first-best outcome is not achieved. In the case of partial deposit insurance, depositors will monitor the bank but they face either strategic uncertainty or the inefficiencies created by a runs-preventing contract. Full deposit insurance clearly creates an incentive problem since the interests of the bank and its depositors are aligned. Thus, even if monitoring costs are 0, the first-best is not obtained.

We consider the robustness of these results with respect to two important assumptions. First, if monitoring was the outcome of the interaction of multiple agents rather than just one, then the conditions for monitoring would not be given by (4) and the optimal action by the government would change. We show elsewhere that the critical value of \( z \) characterized in Proposition 2 is relevant for the case of multiple depositors. In particular, if \( z \geq z' \), then the Nash equilibrium is for no depositor to monitor. That is, if no other depositor monitors, then the remaining agent uses (4) to determine whether or not monitoring is desirable so that \( z' \) is again the critical level of insurance. For \( z < z' \), the symmetric Nash equilibrium will entail monitoring and the probability that any individual agent monitors will increase as \( z \) falls.

Second, suppose that \( q \) was large enough so that, in the absence of deposit insurance, banks would have elected to offer runs-preventing contracts. In such a

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26 These results are contained in an earlier version of this article, available from the authors upon request.
case, the provision of partial deposit insurance can have the perverse effect of increasing the probability of runs. The insurance can make it optimal to abandon the runs-preventing contract and if the insurance is not complete runs can still happen. Thus, while with zero monitoring costs the best runs-preventing contract will involve neither runs nor moral hazard, adding partial deposit insurance can lead to both.

5. CONCLUSIONS

The goal of this article has been to extend the Diamond–Dybvig framework to understand the implications of runs and moral hazard for the evaluation of the costs and benefits of deposit insurance. In our analysis, as in that of Diamond–Dybvig, there is a clear benefit to the provision of deposit insurance as it prevents runs. The costs modeled here are associated with a reduction in the incentives for depositors to monitor, giving rise to riskier investments by intermediaries.

From the perspective of our model, the first-best allocation is achievable with a combination of policies. Deposit insurance is needed to avoid bank runs. Capital requirements are needed to overcome the adverse incentive problems associated with the provision of deposit insurance.

The article has demonstrated that one potential consequence of the combination of an inadequate capital requirement, say due to regulatory failure, with a generous deposit insurance fund is the type of banking instability observed in the U.S. during the 1980s. We therefore believe that our article contributes to an understanding of what happened to many of the failed S&Ls.

This work leaves a number of interesting avenues for future research. For example, we do not explicitly consider here the implications of risk-based deposit insurance plans. The 1991 FDIC Improvement Act mandated a move toward risk-based premia in the United States and a similar program appears to be coming to deposit insurance in Canada. While it might appear that such policies would solve the runs problem without introducing moral hazard, much depends on the timing of moves. If bank owners can adjust their portfolios after premia have been paid, then the problems we analyze here may remain. The premia, once paid, become a sunk cost that will not influence future investment behavior. Of course, in a multiperiod environment, “punishments” can be administered in the future in the form of higher premia, but in the case of banks with depleted capital bases, and therefore nothing much to lose, the punishment might come too late.27

While the model developed here does present simple conditions to achieve the first-best outcome, potential limitations of this solution arise from the presence of moral hazard between bank owners and managers and difficulties in raising

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27 This point is also made by Freixas and Rochet (1997, p. 270). Chan et al. (1992) demonstrate the impossibility of fairly priced deposit insurance in a model with asymmetric information and incentive compatibility constraints. Dewatripont and Tirole (1994) argue that “it is extremely difficult to devise proper risk-based premiums, especially if those are to be determined in a transparent, nondiscretionary manner” (pp. 60–61). They characterize the American approach with premiums ranging from 23 to 31 cents per $100 of deposits as “very timid.”
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
leave the question of the second-best policies in this environment for future
research.

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