LIQUIDITY PROVISION VS. DEPOSIT INSURANCE: PREVENTING BANK PANICS WITHOUT MORAL HAZARD

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Abstract

In this paper I ask whether a central bank policy of providing liquidity to banks during panics can prevent bank runs without causing moral hazard. This kind of policy has been widely advocated, most notably by Bagehot (1873). I show a particular central bank liquidity provision policy can prevent bank panics without moral hazard problems. A key feature of this policy is that the central bank has priority over the assets of the banks it lends to, if they default. I also show that a deposit insurance policy, while preventing runs, can create moral hazard problems.

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1 Introduction

This paper compares a liquidity provision policy with a deposit insurance scheme and shows that the former can prevent bank panics without creating the type of moral hazard problems typically associated with the latter. By comparing liquidity provision policies with deposit insurance this paper sheds some light on the problem of designing an appropriate banking "safety net." This problem has received attention recently because poorly designed institutions often seem to contribute to banking crises, as documented by Caprio and Klingebiel (1996).

The fact that banks can be subject to panics or runs has long been a concern of policy makers. The traditional answer to the problem of bank panics has been to introduce a deposit insurance scheme; the FDIC in the United States is an example. Since the 1980s, deposit insurance schemes in general, and the FDIC in particular, have come under much criticism as they are thought to create moral hazard (see for example Kareken and Wallace (1978) or Boyd and Rolnick (1988)).[1]

This paper considers a different kind of policy intended to prevent bank panics. This policy, which can be traced back at least to Bagehot (1873), consists of providing liquidity to banks in a period of panic. The idea is that a panic can be prevented if banks can obtain enough money to accommodate withdrawals without needing to liquidate illiquid assets. As will be shown, this type of policy can prevent bank panics and does not create moral hazard. The key difference between the two policies is that deposit insurance protects depositors not only in the case of a bank run but also when the bank gets

[1]Several authors have proposed ways to modify deposit insurance schemes that mitigate the moral hazard problem. See for example Boyd and Rolnick (1988), Feldman and Rolnick (1997), Calomiris (1999), Chen (1999), Cooper and Ross (2002).

a low return on its investments. A well-designed liquidity provision policy, instead, preserves the incentives of banks not to invest in risky technologies because they are not bailed out.

The environment I study is a version of the Diamond and Dybvig (1983) model. In this model, deposit insurance and the liquidity provision policy can serve as commitment devices. With deposit insurance, the insurance authority can tax banks and invest directly in the illiquid technology. It is able to commit not to liquidate it and thus guarantee patient depositors that goods will be available when they want to consume. The liquidity provision policy is modeled as in Allen and Gale (1998). The central bank repurchases the illiquid assets and can commit not to liquidate them. At the same time it provides banks–who offer nominal deposit contracts–with cash so they can service all their withdrawing depositors.[2] An important feature of the liquidity provision policy is that the central bank has priority over the assets of the banks it lends to if they default.

Several authors have considered either deposit insurance schemes or liquidity provision policies independently.[3] A few authors have analyzed environments with both. Williamson (1998) considers deposit insurance and discount window lending, but the focus of his paper is different. He shows that when there are restrictions on branch banking, there is a role for both policies. Repullo (2000) asks whether a central bank or a deposit insurance corporation should be the lender of last resort. Although his question is sim-

[2]Champ, Smith, and Williamson (1996), Williamson (1998) also study models of banking with money. Because their models do not consider self-fulfilling bank runs, they cannot be used to study the questions addressed in this paper.

[3]Boyd, Chang, and Smith (2000, 2001), Cooper and Ross (2002), Freeman (1988), Hazlett (1997), Kareken and Wallace (1978) consider deposit insurance. Antinolfi, Huybens, and Keister (2001), Bhattacharya and Gale (1987), Cooper and Corbae (2002), consider a liquidity provision policies.

ilar to mine, his approach is not. He assumes that the central bank and the FDIC have different objective functions and do not try to maximize social welfare. These papers are not directly concerned with moral hazard. The paper closest to mine, in spirit, is Sleet and Smith (2000). These authors consider both liquidity provision and deposit insurance as part of a banking system safety net. Banks arise in their environment because of costly state verification. In their paper, the primary risk faced by banks comes from their lending activities as they invest in risky projects. Sleet and Smith do not, however, consider bank panics. Instead, they are interested in the question of whether or not problem banks should be shut down early. In contrast, in my paper, the main risk faced by the bank is whether depositors will want to withdraw early or not, and the exercise is to design a policy that gives depositors the right incentives.

The rest of the paper is structured as follows. Section 2 presents the model. Section 3 considers a deposit insurance scheme. Section 4 considers the liquidity provision policy. Section 5 concludes.

2 The environment

There are three dates, 0, 1, and 2, and a continuum of depositors and banks, each of mass 1. Each depositor is endowed with an amount ω of the economy's single consumption good. There are two kinds of investment technologies. The *short-term* (storage) technology yields one unit of the consumption good at date t for each unit invested in subperiod $t-1$, $t = 1, 2$. The *long-term* technology yields $Q(z)R$ units of the consumption good at date 2 for each unit invested at date 0, where $R > 1$, $z \in [1, Z]$, for some large Z, and $Q(z)$ is equal to z with probability $1/z$ and 0 with probability $(z-1)/z$.

Banks choose the value z of the technology in which they invest. The long-term technology has a deterministic return when $z = 1$ and choosing a higher z increases the variance of the return of the project without changing its expected value. Moral hazard is said to occur if, in equilibrium, banks choose $z > 1$. The actual value taken by $Q(z)$ for each project is observed by the banks and depositors at the beginning of date 2 and the $Q(z)$ are independent between projects. Since projects' return are independent, the total output of the economy depends only on how much is invested in the long-term and the short-term technology, but not on the choice of z.[4]

Liquidating the long-term technology at date 1 is assumed to carry a cost in terms of the consumption good and returns only $r < 1$. For example, assume that a proportion l of the unit invested is liquidated at date 1, then the technology has return rl at date 1 and $(1-l)Q(z)R$ at date 2.

Households can be of two types: impatient or patient. The impatient type only derives utility from consumption at date 1, and the patient type derives utility only from consumption at date 2. Types are learned at the beginning of date 1 and are private information. Each depositor has a probability $\theta > 0$ of being impatient and a law of large number is assumed to hold so the proportion of impatient depositors in the population is also θ. To keep things as simple as possible, it is assumed that θ is not a random variable.[5]

Let c_t denote the amount of goods consumed at date t. A depositor's expected utility in every period is:

$$U(c_1, c_2, \theta) = \theta u(c_1) + (1-\theta) u(c_2).$$

If depositors are impatient, they only want to consume goods at date $t =$

[4] Chari and Jagannathan (1988), Jacklin and Bhattacharya (1988), Allen and Gale (1998, 2000) consider environment in which total output is random.

[5] Champ, Smith, and Williamson (1996), Chari (1989), Peck and Shell (2003), Wallace (1988, 1990), consider environments where the number of impatient depositors is random.

1, and if they are patient, they only want to consume goods at date $t = 2$.[6] Patient agents can store goods they buy at date 1 with the short-term technology. Alternatively, it could be assumed that they derive utility from the sum of their subperiod 1 and subperiod 2 consumption. The function u exhibits CRRA: $u(c) = \frac{c^{1-\sigma}}{1-\sigma}$, with $\sigma > 1$.[7]

2.1 The planner's problem

Consider a planner who knows the type of each depositor and tries to maximize depositors' expected utility. It solves

$$\max \theta u(c_1) + (1-\theta)u(c_2),$$

subject to

$$i_1 + i_2 \leq \omega, \tag{1}$$

$$\theta c_1 \leq i_1, \tag{2}$$

$$(1-\theta)c_2 \leq Q(z)Ri_2. \tag{3}$$

The solution to this problem, denoted $(c_1^*, c_2^*, i_1^*, i_2^*)$, is characterized by equations (2), (3), as well as

$$u'(c_1) = Ru'(c_2), \tag{4}$$

$$\theta c_1 + \frac{1-\theta}{R}c_2 = \omega. \tag{5}$$

I call this allocation either the planner's allocation or the efficient allocation. Clearly, the planner chooses $z = 1$ since depositors are risk averse. Because

[6]The analysis can be extended to more general preferences as shown by Jacklin (1987) or Jacklin and Bhattacharya (1988).

[7]σ is assumed to be greater than 1 for simplicity. The results could be extended to cases where σ is less, yet close to 1, as long as r is less than 1.

the planner is assumed to know depositors' type, truthful revelation is not an issue. Below, I show the same allocation can be achieved with a liquidity provision policy even though types are unobservable.

2.2 A deposit contract

Suppose a bank offers the following contract: c_1^* units of goods to depositors who withdraw at date 1 and c_2^* to depositors who withdraw at date 2. If everyone believes that only impatient depositors will withdraw at date 1, then it is individually rational for patient depositors to withdraw at date 2 In that case, the allocation obtained in equilibrium with the deposit contract is identical to the planner's allocation.[8]

If, however, everyone believes that patient depositors will withdraw at date 1, then it is individually rational for them to do so. In this case the allocation obtained with the deposit contract is different from the planner's allocation and is associated with a bank run.

If the probability of such an event is perceived to be strictly positive, a bank will no longer want to offer the deposit contract described above. Instead, it will take into account the fact that a bank run might occur and adjust its investment in the long-term and the short-term technology.

Whenever a bank run occurs, the goods available are assumed to be distributed equally among all depositors. Eliminating Diamond and Dybvig's sequential service constraint in this way simplifies the presentation without changing the main result. Under this assumption, all agents strictly prefer to deposit their endowment in banks.

[8]As pointed out by Jacklin (1987), it is important that depositors cannot resell their claims on the banks on a secondary market. This point is also discussed in Haubrich and King (1990) and von Thadden (1999).

2.3 Sunspot

A common approach to dealing with multiple equilibria in this literature is to assume that bank runs are triggered by a sunspot (see, for example, Benthal et al. 1990, Cooper and Ross 1998 and 2002, and Freeman 1988 among others).[9] Assume depositors have the following beliefs:

Baseline beliefs: If a sunspot is observed, everyone believes patient depositors withdraw at date 1, otherwise everyone believes they withdraw at date 2.

In each period, depositors in a fraction n of the banks observe a sunspot. In the remaining banks, depositors believe only impatient depositors will withdraw at date 1. n is assumed to be a random variable distributed on the interval $[0, 1]$ according to a p.d.f. f. Let $\mu = E(n) = \int nf(n)dn$. The distribution f could have a mass point at zero, so that with positive probability, no banks are affected by the sunspot.

To simplify the exposition I assume banks are not allowed to suspend convertibility. In other words, banks cannot commit not to liquidate the long-term technology and refuse service to some depositors who want to withdraw early. In this I follow Allen and Gale (1998), Chang and Velasco (2000 and 2001), and Copper and Ross (1998 and 2002). Several arguments can be offered in defense of this assumption. Chang and Velasco (2001) suggest that it might be undesirable to allow suspension of convertibility because of informational frictions. Indeed, a moral hazard problem could occur where a bank has an incentive to claim a bank run is taking place in order to default on its obligations. Diamond and Rajan (2001) study a model of banking in which the threat of runs disciplines bankers. In the context of that model, policies such as suspension of convertibility undermine the ability of banks

[9] Also, Ennis (2003) argues that empirical evidence is not inconsistent with the idea that bank run can be triggered by sunspots.

to provide liquidity.[10] Also, historically the ability for banks in the US to suspend convertibility was limited. Diamond and Rajan (2001) note that "banks were allowed to suspend convertibility only when they agreed to do so as a collective..."

2.4 Equilibrium

This section characterizes an equilibrium for this economy. Banks are assumed to maximize profits. Because of perfect competition, banks will offer, in equilibrium, a deposit contract that maximizes the utility of the representative depositor.[11] Depositors' beliefs are coordinated by a sunspot as described above, and depositors choose when to withdraw so as to maximize their utility. Hence, impatient depositors always withdraw at date 1, since they get no utility from consuming later. Patient depositors will withdraw at date 1 if their bank is affected by a sunspot and at date 2 otherwise.

Let c_r denote the consumption enjoyed by depositors in this case. The bank's problem can be written

$$\max(1-\mu)[\theta u(c_1) + (1-\theta)u(c_2)] + \mu u(c_r)$$

subject to equations (1), (2), (3), and

$$c_r = i_1 + ri_2. \tag{6}$$

Since depositors are risk averse, banks have no incentive to choose $z > 1$. Hence equation (3) is given by $(1-\theta)c_2 \leq Ri_2$.

[10] Deposit insurance would also undermine the ability of banks to provide liquidity in that kind of model. As will be noted below, the liquidity provision policy that I consider does not.

[11] Allen and Gale (1998), Cooper and Ross (1998), Schreft and Smith (1998), among others, adopt this approach.

From the first order conditions, one can write

$$\mu(1-r)u'(c_r) + (1-\mu)u'(c_1) = (1-\mu)Ru'(c_2). \tag{7}$$

Lemma 1 *A unique solution exists to the bank's problem.*

All proofs are in the appendix.

Let $(\hat{c}_1, \hat{c}_2, \hat{i}_1, \hat{i}_2)$ denote the solution to the bank's problem.

Lemma 2 $\hat{i}_1 > i_1^*$.

The intuition for this result goes as follows: When there is a strictly positive probability of a panic, banks prefer to invest a little more in the short-term technology because this increases the resources available in case such an event occurs.

Bank panics create two different distortions. On the one hand, the long-term technology is liquidated in the banks affected by the sunspot. On the other hand, the investment of all banks is distorted, compared to the planner's allocation.

Instead of offering the contract described above, banks could offer a contract such that runs never occur. In order to do that, they need to reduce the amount promised to impatient depositors enough so that even if all depositors pretend to be impatient there will be some resources left over. Cooper and Ross (1998) study such contracts. In the present environment, as in their paper, if μ is sufficiently small banks will prefer the contract described above to the run-preventing contract. For the remainder of the paper it will be assumed μ is small.

3 Deposit insurance

This section considers a policy resembling deposit insurance and shows that it can prevent bank panics but generates moral hazard. Assume there is a special agent called the insurance authority (IA) which can tax the consumption goods held by depositors at date 0, invest in the long-term technology, and distribute the proceeds of its investments to banks and/or depositors. A *deposit insurance policy* is the complete description of the IA's behavior in each state of the world. Such a policy is characterized by a level of tax, τ, a level of investment, and a set of rule on how the proceeds of the investment are distributed to banks and depositors.

The distribution rules for the IA are as follows: Goods from the deposit insurance fund are given to patient depositors whose banks declare bankruptcy until either these depositors have as much goods as the other patient depositors or the fund is exhausted. If there are goods left over in the fund they are distributed equally among all the banks which did not declare bankruptcy.

The insurance authority is assumed to observe neither the value of z chosen by banks nor the realization of $Q(z)$. This extreme assumption is made for simplicity, what is needed is that the IA does not have a perfect knowledge of z and $Q(z)$. If the IA could observe, or infer, z with certainty then the moral hazard problem could be eliminated by pricing the risk appropriately.

Banks choose how to invest their deposits, net of the deposit insurance premium, and offer a deposit contract to depositors, taking into account the deposit insurance policy. As above, because of competition, these decisions maximize the depositors' expected utility.

3.1 Deposit insurance when there is no moral hazard

This section shows that deposit insurance can prevent panics when the value of z is restricted to be 1. If there is no limit to the amount the IA can tax, it can eliminate the role of banks by taxing exactly $\frac{1-\theta}{R}c_2^*$, the amount banks would want to invest in the long-term technology. In that case, banks invest all their net-of-premium deposits in the storage technology and declare bankruptcy at date 1. Patient depositors have no incentive to withdraw early, since they are guaranteed to receive c_2^* from the IA, and the efficient allocation is obtained.

To make the problem interesting, I assume the IA taxes the minimum amount necessary to prevent panics.[12] The efficient allocation is achieved when banks invest i_1^* in the short term technology, $i_2^* - \tau$ in the long-term technology, and offer the deposit contract $\{c_1^*, c_2^*\}$, provided there is no bank run.

Proposition 1 *Define* $x = \frac{R}{R-r}\left[\theta + r\left(\frac{\omega - i_1}{c_1}\right) - \frac{r}{R}\right]$. *Let* x^* *denote the value of* x *if* $i_1 = i_1^*$ *and* $c_1 = c_1^*$. *If* $z = 1$ *and* $\tau \geq (1 - x^*)c_1^*/R$, *then there is no bank run with deposit insurance.*

At date 2, along the equilibrium path, banks have $c_2^* - \frac{1-x^*}{1-\theta}c_1^*$ from their investment in the long-term technology. Since there are no bank runs, each of them also receives $\frac{1-x^*}{1-\theta}c_1^*$ from the IA. Off the equilibrium path, banks

[12] This would be uniquely optimal if the return the IA were able to get on its investment were $\tilde{R} < R$. Such an assumption could be justified by assuming that banks are better at identifying good projects than is the IA. In the US, funds paid by banks to the FDIC are invested in government securities. Alternatively, one could assume that the IA lets bank put some of their long-term technologies in a safe box so that they cannot be liquidated at date 1. In that case, administering or monitoring the safe box could be costly, implying a lower return for these investments. Assuming that the investment of the IA has a return of R is the most favorable case for deposit insurance.

affected by a run have to liquidate their long-term investment and thus have no resource of their own for their patient depositors. However, they can count on at least c_1^* for each patient depositor from the IA. Hence, bank runs are prevented because the IA can guarantee patient depositors never consume less than c_1^* if they withdraw late, regardless of other depositors' behavior. The equilibrium allocation with deposit insurance when $z = 1$ is thus efficient and unique.

Deposit insurance works like a commitment device for banks which are, by assumption, unable to commit not to liquidate the long-term technology on their own. The IA, on the other hand, guarantees that the goods it invested in the long-term technology will not be liquidated. Hence, the IA provides a guarantee to patient depositors that goods will be available at date 2.

3.2 Deposit insurance and moral hazard

This section shows that with deposit insurance banks will choose $z > 1$. The IA is assumed to be unable to target deposit insurance only to those banks that are affected by the sunspot. Once a deposit insurance scheme is in place, any bank in trouble can have access to it, whether its trouble arise from pessimistic expectations from its depositors or from excessively risky investment.[13]

If it were possible to make the deposit insurance policy contingent on the sunspot, moral hazard could be easily prevented by denying insurance to banks that have made excessively risky investment. Note, however, that the results in the paper hold if the IA observes the sunspot imperfectly; i.e.,

[13] To maintain symmetry the liquidity provision policy will also be assumed to be non-contingent on the sunspot. Even in that case, it will be shown that liquidity provision does not lead to moral hazard.

the IA makes mistakes sufficiently often and bails out banks which are not affected by the sunspot. The idea is that it might be difficult for the IA to know precisely what caused a bank's trouble; whether it was excessive risk taking or pessimistic depositors.

If a bank has invested in a risky technology that failed, it must declare bankruptcy after it observes the realization of $Q(z)$. Bankrupt institutions hand over all their assets to the IA which will make payments to depositors who have a claim on these banks.

As before, $\tau = (1 - x^*) c_1^*/R$ and the deposit insurance fund is distributed among patient depositors whose banks have declared bankruptcy until these depositors have as much as the other patient depositors or the fund is exhausted. Any remainder is distributed equally among all non-bankrupt banks.

Proposition 2 *With deposit insurance banks choose $z > 1$.*

Cooper and Ross (2002) present a similar result.

In equilibrium, patient depositors from banks whose projects have failed consume less than the patient depositors from the other banks. In other words, the deposit insurance fund is exhausted before the consumption of the former depositors reaches that of the latter. This means that the expected utility of depositors is lower than it would be under the efficient allocation. This is true despite the fact that the total amount of goods consumed in this economy is independent of the choice of z (since the risky technologies are mean preserving spreads of the safe one). If depositors were perfectly diversified between banks, there would be no welfare cost of moral hazard.[14] Of course, with deposit insurance, depositors prefer not to be diversified.

[14]The cost of moral hazard would reappear if the expected value of the risky project was lower than that of the safe projects.

Deposit insurance prevents bank runs and thus guarantees a unique equilibrium, but this equilibrium can be really bad. Banks take on too much risk and many fail. For μ sufficiently small, the cost of moral hazard will exceed the cost of bank runs, so deposit insurance will reduce the expected utility of depositors.

Although it is possible to mitigate the moral hazard problem by reducing the amount of insurance provided by the IA, the following proposition can be proved.

Proposition 3 *For some parameter values, either deposit insurance induces moral hazard or it cannot prevent bank panics.*

4 Liquidity provision

This section considers a liquidity provision policy which can prevent bank panics and does not generate moral hazard. Assume there is a special agent called the central bank (CB) which has the ability to create intrinsically worthless and non-falsifiable pieces of papers called money. A *liquidity provision policy* is the complete description of the CB's behavior in each state of the world.

The liquidity provision policy in this paper is as in Allen and Gale (1998). The CB can exchange money for assets held by the banks at date 1 and commit to exchange these assets back at date 2 for the money it had distributed. A liquidity provision policy is given by the rates at which the CB exchanges assets for money at date 1 and money for assets at date 2.

Banks own the goods invested in the long-term technology and can sell the rights to these goods to the CB. This section considers a policy under which the CB buys and sells these rights at the same price, implicitly lending funds at zero interest rate. As in Allen and Gale (1998), deposit contracts are assumed to be expressed in nominal terms. Hence, banks can use the money they obtain to pay depositors which announce they are impatient without having to liquidate the long-term technology. Indeed, since the rights to these goods have been sold, the CB now decides whether they should be liquidated. This provides a guarantee that there will be enough goods left for patient depositors at date 2. At the beginning of date 2 a bank must buy its assets back from the CB, before it can pays its depositors.

Consider what happens if the CB lends some money M to a bank and all the bank's depositors withdraw at date 1. The bank will give each of its depositors a combination of cash and goods. Patient depositors are willing to sell the goods they have in exchange for cash. The price level will adjust so that after the exchange impatient depositors hold only goods and patient depositors hold only cash. Each impatient depositor ends up with an amount c_1^* of goods, which corresponds to the planner's allocation. At date 2, the bank needs the cash held by patient depositors in order to buy the long-term projects back from the CB. The price level will adjust so that depositors obtain all the goods invested in the long-term technology. Each patient depositor ends up with an amount c_2^* of goods. With such a scheme, patient depositors are indifferent between withdrawing at date 1 or 2.[15] However, if the CB charges the bank an arbitrarily small fee $\varepsilon > 0$ for the liquidity, patient depositors will strictly prefer to withdraw at date 2.

[15]Note that in an environment of the type studied by Diamond and Rajan (2001) this kind of liquidity provision policy does not remove the commitment value of deposits in the way deposit insurance or suspension of convertibility does. Indeed, if the banker tries to renegotiate, then all depositors withdraw early. Any liquidity that the banker is able to secure from the CB is distributed to depositors at date 1. At date 2, patient depositors can redeem this money with their banker or directly at the CB. The banker is thus unable to extract any resources from an attempt to renegotiate.

To maintain symmetry with the deposit insurance policy, it is assumed the liquidity provision policy cannot be made contingent on the sunspot. Thus, the CB cannot choose not to lend to banks that are unaffected by the sunspot. It is assumed the CB can observe how much banks invest in the short-term and in the long-term technology. Hence, it can limit access to liquidity for banks that invest too little in the short-term technology.[16]

Proposition 4 *With the liquidity provision policy, there are no bank runs.*

This policy works as in Allen and Gale (1998). As was the case with deposit insurance, the equilibrium allocation under the liquidity provision policy is efficient. This policy is also robust to the introduction of aggregate uncertainty about the amount of impatient depositors. The CB can always repurchase enough assets to prevent a panic. The liquidity provision policy plays the role of a commitment device as well. The CB allows banks to pay their nominal contracts without having to liquidate the long-term technology. The CB thus provides a guarantee that each bank is unable to provide on its own.

4.1 Liquidity provision and moral hazard

With moral hazard, banks may need to declare bankruptcy if they invest in a risky project that fails. The timing at date 2 is as follows. First, banks observe the realization of $Q(z)$. Next, they announce whether or not they

[16]If the CB does not impose this restriction, banks have an incentive to invest all their deposits in the long-term technology and borrow cash from the CB to give to their impatient depositors. This attempt to free ride on the short-term investment of other banks would distort the equilibrium allocation. A similar problem arises in Allen and Gale (1998) although they do not mention it. I am indebted to Nobu Kiyotaki for pointing this out to me.

are bankrupt. If a bank is bankrupt, the CB first repays itself, then the depositors obtain what is left.[17] Finally, if a bank stays in business it buys its assets back from the CB, then pays its patient depositors.[18]

Although the CB owns the rights to proceeds of the long-term technology, it is assumed that the banks still manage the projects and have better information about their returns that the CB does. Alternatively, I could have assumed that banks must always buy their assets back from the CB (they can do that since they still hold the cash they received from the CB at date 1) and declare bankruptcy when they are unable to service their patient depositors.

Proposition 5 *Under the liquidity provision policy banks choose $z = 1$.*

Without the priority rule, this policy might not prevent moral hazard. If a bank chooses a high z and gets a bad realization of $Q(z)$, it might want to pay out the cash it has on hand to the patient depositors and declare bankruptcy, leaving the CB with assets worth very little. With the priority rule, however, the patient depositors only get paid after the CB. This gives them the incentive to deposit in banks that choose low values of z.

This policy works even though the CB does not observe z, and the realization of $Q(z)$. The timing here is important; if $Q(z)$ were observed by banks at date 1, this policy would not be able to prevent bank runs. This is

[17]The fact that the CB has priority of the assets of the banks if they declares bankruptcy is important. This is consistent with the rules under which the Federal Reserve operates. Discount window loans from the Fed are always collateralized and the claim associated with such loans are superior to any other party.

[18]Recall, the CB can observe how much banks invest in the short-term and in the long-term technologies. However, it is unable to observe z, the riskiness of the long-term technology in which a bank has invested. The idea is that it is easier for the CB to gather information on the size of a bank's investment in government bonds, compared to the size of its loans portfolio, than it is to ascertain the riskiness of that portfolio.

because all patient agents would claim to be impatient when the technology has low return. One can think of a situation where the return of the technology is observed early as having more information asymmetry as when it is observed late. The model then suggests that what Bagehot (1873) means when he claims that the CB should lend against "good securities" is that this asymmetry should not be too big. Indeed, it is not the riskiness of the securities that matters; the liquidity provision policy would still work in an environment where banks optimally invest in risky technologies.

5 Conclusion

This paper shows a liquidity provision policy can prevent bank runs without causing the kind of moral hazard problems associated with deposit insurance. I study a simple model of banking in which both policies can be analyzed and show that if moral hazard can occur a banking system provides less expected utility to depositors with deposit insurance than with the liquidity provision policy. With deposit insurance, banks are bailed out when their risky investments fail and that gives them incentive to take on more risk than they would otherwise. This is not the case with the liquidity provision policy because it does not affect the bank's return in an asymmetric way.

This result does not mean that there can be no role for deposit insurance in a financial safety net. For example, deposit insurance can have a role when the primary source of risk for banks comes from their lending activities, as in Sleet and Smith (2002). Williamson (1998) also presents an environment in which both deposit insurance and liquidity provision can play a role. This paper, however, suggests that if the insurance authority finds it difficult to distinguish failures due to runs from those resulting from bad investments, and if its sole purpose is to prevent bank panics, then liquidity provision should be preferred to deposit insurance.

6 Appendix

Proof of lemma 1

It is enough to show that there exists a unique value of i_1 such that equation 7 is satisfied. Note that if $i_1 \to \omega$, then $c_2 \to 0$ and the RHS of 7 will tend to infinity while the LHS is finite. If $i_1 \to 0$, then $c_1 \to 0$ and the LHS of 7 will tend to infinity while the RHS is finite. The proof is complete since u' is a strictly decreasing function.

Proof of lemma 2

Equation 7 can be rewritten as $\mu(1-r)u'(c_r) = (1-\mu)[Ru'(c_2) - u'(c_1)]$. Since the LHS of this expression is strictly positive, it must be the case that $Ru'(c_2) > u'(c_1)$. The proof follows from the fact that i_1^* implies $Ru'(c_2) = u'(c_1)$.

Proof of proposition 1

It is useful to first explain the meaning of x: It is the maximum number of depositors that can receive an amount of consumption c_1 at date 1 such that there will be enough goods available at date 2 for the remaining depositors to also consume c_1. Formally,

$$c_1 x = i_1 + r\left(\omega - \tau - i_1\right)$$

indicates that a mass x of depositors can receive c_1 at date 1 if i_1 has been invested in the short-term technology, τ has been taxed, and $(\omega - \tau - i_1)$ has been invested in the long-term technology and liquidated. The amount taxed will be enough to provide c_1 at date 2 to the remaining $1 - x$ depositors if

$$R\tau = (1 - x)\, c_1.$$

Eliminating τ in these two equations yields the value of x given above. Note $x \geq \theta$.

Now consider the worst case scenario where all banks are subjected to a panic and must declare bankruptcy ($n = 1$). If exactly $x^* - \theta$ patient depositors go to the bank at date 1 they receive c_1^* and there is no goods left in the banks. However, the IA has just enough goods to give c_1^* to the $1 - x^*$ remaining patient depositors. If less than $x^* - \theta$ patient depositors go to the bank at date 1 they still get c_1^*, but now there are goods left over in the banks. Because each unit not liquidated at date 1 yields R units at date 2, the other patient depositors receive more than c_1^*. If more than $x^* - \theta$ patient depositors go to the bank at date 1, they each receive less than c_1^*. The other patient depositors receive more than c_1^* because there are less than $1 - x^*$ depositors to give goods to. It follows that a patient depositor can never be better off going to the bank at date 1. This remains true if only some banks are subject to panics because there will be less depositors needing goods. This completes the proof.

Proof of proposition 2

Suppose, on the contrary, that all banks choose $z = 1$, and consider the case of a bank that deviates. Since the insurance fund contains $(1 - x^*)\, c_1^*$ and none of the other banks will declare bankruptcy, the patient depositors in the deviating bank are guaranteed to consume at least c_2^*. If the deviating bank's project fails and it must declare bankruptcy, the patient depositors will get exactly c_2^* (since each bank has measure zero). If the project succeeds, the patient depositors get $z\left(c_2^* - \frac{1-x^*}{1-\theta}c_1^*\right)$ from the successful project and $\frac{1-x^*}{1-\theta}c_1^*$ from the deposit insurance fund when it is liquidated. Thus, the utility of the patient depositors in this bank is:

$$\frac{1}{z}u\left(z\left(c_2^* - \frac{1-x^*}{1-\theta}c_1^*\right) + \frac{1-x^*}{1-\theta}c_1^*\right) + \frac{z-1}{z}u\left(c_2^*\right).$$

Taking derivatives with respect to z, and using the fact that u is CRRA, yields

$$\frac{1}{z^2}\left\{-u\left(zc_2^* + (1-z)\frac{1-x^*}{1-\theta}c_1^*\right) + z\left(c_2^* - \frac{1-x^*}{1-\theta}c_1^*\right)\left[zc_2^* + (1-z)\frac{1-x^*}{1-\theta}c_1^*\right]^{-\sigma} + u\left(c_2^*\right)\right\}.$$

Evaluated at $z = 1$, this expression is

$$u(c_2)(1-\sigma)\frac{c_2 - \frac{1-x}{1-\theta}c_1}{c_2}.$$

Since $\sigma > 1$, $u(c) < 0$, for all $c \geq 0$, and the above derivative is positive at $z = 1$ so the deviating bank would choose $z > 1$. In fact, since the second derivative is positive as well, the deviating bank would choose z as large as possible.

Proof of proposition 3

In order to prevent panics, the IA needs to promise patient depositors at least c_1^*. I will show, for certain parameter values, that even in this case deposit insurance induces moral hazard.

Assume $z \in \{1, 2\}$. Thus there is only one alternative to the safe technology. I will show the proposition is true if $\mu = 0, \sigma = 1$, and $r > R - 1$. By continuity, it will also hold if μ is not too big, and σ not too far above 1.

I need to show the expected utility from investing in the risky long-term technology is greater than investing in the safe technology. This means, since $\sigma = 1$,

$$\frac{1}{2}\ln[2(c_2^* - \frac{1-x^*}{1-\theta}c_1^*) + \frac{1-x^*}{1-\theta}c_1^*] + \frac{1}{2}\ln[c_1^*] > \ln[c_2^*].$$

Note $\sigma = 1$ implies $c_2^* = Rc_1^*$ so that the above expression can be written

$$\ln[c_2^*] + \ln[2 - \frac{1-x^*}{1-\theta}\frac{1}{R}] + \ln[c_2^*] - \ln[R] > 2\ln[c_2^*].$$

After eliminating c_2^* and taking the exponential of each side, one gets

$$R(2+r) > R^2 + 1 + r,$$

which is equivalent to $r > R - 1$.

Proof of proposition 4

By assumption, the CB can inject as much cash as it wants in the economy. A patient depositor who withdraws early will receive goods and cash worth c_1^*. A patient depositor will be willing to exchange the goods is has for cash, and this exchange will leave the depositor with the same value. Since the cash injection by the CB guarantees that the long-term technology will not be liquidated this amount is strictly less than the amount received by depositors who withdraw late. Hence patient depositors have no incentives to withdraw early.

Note that banks are willing to borrow since it does not affect their profits as they are left with exactly the same amount of goods. And since the CB sells goods back to banks at the same price it has bought them, all the money injected is removed.

Proof of proposition 5

Bank runs are prevented by giving banks enough cash to pay out the depositor claiming to be impatient. Thus, the amount of goods available for depositors claiming to be patient is unchanged. Also, the amount of goods available to a bank is not affected by the choice of z made by other banks. Since depositors are risk-averse, and the long-term technology has the same expected return for all z, but is riskier for a bigger z, banks choose to minimize the risk and set $z = 1$.

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