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Surety Bonds and Moral Hazard in Banking

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JEL Classification

G21, G28

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1 Introduction

Sometimes good ideas are left aside for no good reason. In this paper, we suggest that surety bonds for banks are one such idea for banking policy.

The last financial crisis reopened the debate on how to improve the stability of the financial system. After the failures and near-death experiences of banks in the United States and elsewhere after the financial crisis, there have been many proposals to raise banks' required capital.[1]

Establishing capital requirements is one of the three pillars of macroprudential regulation. Deposit insurance gives banks an incentive to hold less capital and capital requirements counter this tendency. If shareholders have a larger stake in the bank, the incentive to engage in risk are lower because shareholders are less likely to be bailed out. The positive effects of capital requirements on risk have been widely analyzed from a theoretical point of view (see Buser, Chen and Kane 1981, Repullo 2004 and Morrison and White 2005). Nevertheless, other studies have reached negative results about the efficacy of capital requirements (Blum, 1999, Koehn and Santomero, 1980). Overall, the theoretical literature has raised doubts about the effects of capital requirements on risk (Hellman, Murdock and Stiglitz 2000, VanHoose 2007, Gale 2010 and Plantin 2015).

In particular, Hellman, Murdock and Stiglitz (2000) analyze moral hazard in a dynamic model, and show that capital requirements are not an efficient tool. Capital requirements reduce the incentive to increase risk by putting bank equity at risk. However, they also have a perverse effect of harming banks' franchise value, thus encouraging risk. In Hellman et al.'s setup, Pareto efficient outcomes can be achieved by adding interest rate controls as a regulatory instrument. This result is in line with Keeley's well-known paper (1990). Keeley argues that banking competition erodes the value of banks' charters and banks are less likely to take risks that might result in failure if the banks' charter has value and is lost on failure.

[1] Greenspan (2010) suggested that the minimum bank capital be raised substantially. This would reduce the probability of banks failing if they hold similar assets to what they held before the introduction of a higher capital requirement.

Other strands of research have examined other mechanisms to enhance prudential regulation. These include the use of subordinated debt (Wall 1989, Evanoff and Wall 2000), contingent convertible bonds and the combination of capital and liquidity requirements (Calomiris, Heider and Hoerova 2015, De Nicolò, Gamba and Lucchertta 2015).

There also have been proposals for different forms of capital, not just a higher level. For example, Acharya et al. (2016) suggest that banks be required to have capital that is held as a cushion but not used to fund typical banking business. If a bank fails idiosyncratically, the bank's capital is forfeited. In such circumstance, it is thought to be most likely that failure is due to bad management, fraud or careless monitoring of the bank by its owners rather than just bad luck. The loss of this capital raises the cost of such a failure and makes it less likely. This uses Keeley's proposition in a different way.

In this paper, we suggest that a different form of capital, a surety bond would be a solid part of regulatory reform. Shareholders would be required to post a surety bond when they receive a charter.[2] The amount put up by the banks' owners would be invested in marketable securities and the stockholders in the bank would receive the income from the bond as long as the bank does not fail. If the bank fails, the funds would be available to bank regulators to pay off the banks' liabilities. In this case, investors would receive the remaining funds, if any. This proposal for a surety bond can be viewed as an indirect response to Allen, Carletti and Leonello's (2011) call for innovative reforms in deposit insurance.

Such a bond is similar to capital in some respects and different in others. This surety bond is an asset that generates income as long as the bank is in business. The assets would not be invested in banking, so a decrease in a bank's business will not in itself affect the bank's income from the surety bond. If the bank fails, the surety bond would be used to pay holders of the bank's liabilities, and investors would receive the rest, if any. We show that the surety bond is a way of creating charter value and solves the moral hazard problem that arises because of deposit insurance. We also demonstrate that capital requirements alone

[2]This would be a "bond" in the sense of a posted amount in the country's currency which is forfeited in the event of failure, not a bond in the sense of a debt security.

cannot prevent this moral hazard problem in our model. However, under certain conditions, a sufficiently high level of capital with no deposit insurance can prevent bank runs and does not introduce moral hazard.

We model an economy with a continuum of depositors and investors. Banks have access to long-term investment assets which provides depositors with higher expected welfare. In particular, at $t = 0$, banks can choose between storage and two assets with the same expected return and different levels of risk. We solve for the decentralized banking system's equilibrium as a benchmark. We show that banks will be subject to runs. Then, we introduce investors, and show that under certain conditions banks can raise enough capital to avoid failures. This result is in line with a proposal by the Federal Reserve Bank of Minneapolis (Federal Reserve Bank of Minneapolis 2017). However, in other circumstances, the equilibrium with capital may not be feasible. In that case, deposit insurance is introduced to prevent bank runs, but at the expense of moral hazard. We demonstrate that capital requirements alone cannot prevent the moral hazard problem created by deposit insurance. We then introduce a surety bond, which turns out to be an effective policy to prevent moral hazard problems in the presence of deposit insurance.

This proposal is similar in some respects to the proposal by Acharya, Mehran and Thakor (2016) and different in others. They assume that assets should be invested in Treasury securities, which is not obvious. Such an investment might induce undesirable asset substitution on banks' balance sheets. A market portfolio of stocks might be more likely to generate a flow of income to banks' stockholders that would not induce banks to take on extra risk due to the low income from Treasury securities. In effect, it would be a portfolio of equities held in trust for the banks' stockholders. Acharya et al. (2016) take it for granted that funds should be transferred from the bond account to the bank's capital when losses occur and bank capital falls. An alternative solution is to permit no such transfers and require the bank to operate as if the bond account did not exist other than the receipt of income by stockholders as long as the bank is in business (as in Kane 1987). In this way, the bond is a lump-sum receipt of income to the banks' owners independent of the bank's activities other than staying open. This ties the surety bond to charter value.

Analytically, a surety bond is a way of creating charter value, but unlike Keeley (1990) or Hellman, Murdock and Stiglitz (2000), it does not require welfare-reducing restrictions on competition to generate positive rents. Because the bond can be lost upon failure, banks will take actions - such as taking less risk - to make failure less likely.

This proposal also is similar to a common historical policy in the United States – a requirement that stockholders in banks have double liability (see Macey and Miller 1993, Grossman 2001, 2007). Stockholders were liable up to the amount of subscribed capital in the bank but, in the event of failure, stockholders were liable for the same amount again. The advantage of a surety bond is that the funds are readily available in the event of failure and stockholders cannot try to avoid the levy by, for example, selling their bank shares to insolvent people. Kane (2000) discusses in a general way how a scheme such as ours could work, pointing out the equivalence of pre-paid extended liability and a surety bond explicit. Osterberg and Thompson (1991) compare surety bonds to subordinated debt. Their major conclusions are that neither matters if deposit insurance is correctly priced. If deposit insurance is mispriced, the amount of subordinated debt issued and the size of any surety bond have important effects on the returns on banks' liabilities. We do not examine subordinated debt, which would require a substantial increase in the complexity of the model. We do examine whether a surety bond can prevent runs on banks and losses to depositors and the insurance fund.

The rest of the paper is organized as follows. The next section, section two, presents the basic features of the model. Section three then considers a decentralized economy with banks and no capital. We show that this economy is subject to runs. Section four introduces investors and shows that under certain conditions banks find it optimal to raise enough capital to avoid failures. In this equilibrium, capital arises endogenously, without the need of regulation. However, if the cost of capitalizing banks exceeds the cost of runs or there exist market imperfections that lessen capital, then the equilibrium with capital and no runs may not be feasible. Section five introduces deposit insurance to prevent runs and shows that deposit insurance introduces a moral hazard problem. Section six analyzes capital requirements in the presence of deposit insurance while section seven focuses on the surety bond. The last section contains our concluding remarks.

2 The model

We consider a three period economy ($t = 0, 1, 2$) with one good. The setup is similar to Diamond and Dybvig (1983) in many but not all respects. There is a continuum of agents of measure one. These agents receive an endowment of one unit at $t = 0$ and can deposit the endowment in a bank or store it on their own. Storage of one unit at $t = 0$ yields one unit at $t = 1$ and one unit at $t = 2$. This technology is available to consumers and to banks. All consumers are ex-ante identical, but are subject to a liquidity shock at $t = 1$. A fraction γ of consumers becomes impatient and places value only on consumption at $t = 1$ with $\gamma \in (0, 1)$. Patient consumers are indifferent between consuming at $t = 1$ or $t = 2$. The fraction $1 - \gamma$ of consumers are patient. At $t = 0$, depositors do not know whether they will be impatient (type-1) or patient (type-2) at $t = 1$. We assume that if impatient agents consume less than $r > 1$ of the good at $t = 1$, then their utility is lower by $\pi > 0$.[3] The utility function of a type-1 agent is

$$U_1(c_1, \pi) = \begin{cases} c_1 - \pi & \text{if} \quad c_1 < r \\ c_1 & \text{if} \quad c_1 \geq r \end{cases} \tag{1}$$

and the utility function of a type-2 agent is

$$U_2(c_1, c_2) = c_1 + c_2. \tag{2}$$

[3]We use the same utility function as in Chen and Hasan (2006, 2008) and Hasman et al. (2011). Agents normally face fixed payments but sometimes they require extra funds to deal with special contingencies (so as to cover r). If they do not have enough cash, they face some costs. Then, the variable π is a liquidity loss in utility.

There are three types of assets available to the bank in this economy. As mentioned above, The first is the storage technology. Storage of one unit at $t = 0$ provides a total of one unit at $t = 1$ and $t = 2$. Second, there is a risky long-term asset, asset A, which transforms one unit at $t = 0$ into one unit at $t = 1$ or into R_h^A units with probability p^A and $R_\ell^A = 1$ with probability $1 - p^A$, at $t = 2$. There is a second long-term asset (asset B) that takes one unit at $t = 0$ and transforms it into R^B units with probability p^B and zero with probability $1 - p^B$, at $t = 2$. Asset B is sufficiently illiquid at $t = 1$ that it is worthless if liquidated at $t = 1$. The probabilities of high and low returns on these assets are independent. Both the storage technology and asset A yield the same amount, if liquidated at $t = 1$, one unit. This implies that the storage technology and asset A are perfect substitutes to satisfy the demand at $t = 1$ by impatient depositors. To simplify notation, we assume that storage always is used in equilibrium to pay impatient depositors.

The returns on the assets satisfy

Assumption 1:

$$R_h^A < R^B \tag{3}$$

$$p^A \geq p^B \tag{4}$$

Asset A's return is lower in its high state than asset B's return in its high state. The probability of a high state for asset A is greater than or equal to the probability of a high state for asset B. Asset A has a return of one in its low state and asset B has a return of zero.

The expected returns on the assets satisfy

Assumption 2:

$$p^A R_h^A + (1 - p^A) R_\ell^A = p^B R^B + \left(1 - p^B\right) 0 \tag{5}$$

that is, the assets have the same expected return. The above equation can be written as

$$p^A R_h^A - p^B R^B = -(1 - p^A) \tag{6}$$

We know that $-(1 - p^A) < 0$ and so

$$p^A R_h^A < p^B R^B \tag{7}$$

The expected return on asset A, considering only the high state, is lower than the expected return on asset B, considering only the high state.

Finally, we make

Assumption 3:

$$p^B R^B > p^A R^A > r > 1 \tag{8}$$

The expected return on assets A and B considering only the high state all are greater than the return r necessary for early consumers to avoid the decrease in utility associated with being an early consumer and having consumption less than r. Finally, r itself is greater than 1 which means that early consumers have a fixed loss of utility π if their consumption is not sufficiently greater than one.

All agents receive a perfect signal at $t = 1$ regarding the assets' returns at $t = 2$. There is no sequential-service constraint: if depositors decide to withdraw all their deposit at $t = 1$, all consumers receive the liquidation value of the assets held by the bank. Each depositor's type, which even the depositor does not know until $t = 1$, is private information at $t = 1$ which implies that runs by patient depositors cannot be prevented.

We assume a perfectly competitive banking industry, which absent externalities implies that we can solve for equilibrium by maximizing the expected utility of depositors subject to a zero profit constraint. Any impatient agent who invests her endowment in the storage technology receives one unit of the good for consumption. As a result the impatient consumer

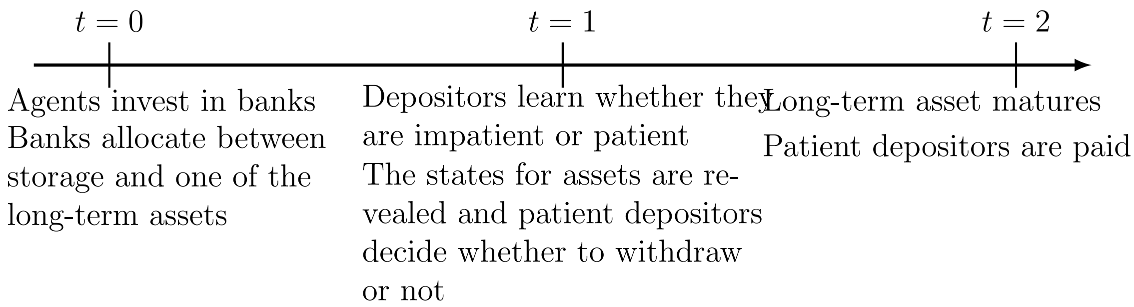

Figure 1: Sequence of events

using the storage technology always receives the utility penalty π. The existence of a banking industry that promises $c_1 \geq r$ can increase her utility. At $t = 0$ each bank offers a deposit contract c_t $(t = 1, 2)$ to agents in exchange for their endowments, where c_t denotes the maximum amount of the good that depositors can withdraw at date t.

The sequence of events is as follows. At $t = 0$, agents invest in banks. The bank then invests the receipts between storage and one of the long-term assets. At $t = 1$, agents discover whether they are impatient or patient, they receive the public signal and decide whether to withdraw their funds from banks. At $t = 2$, the long term asset matures and patient depositors are paid. Figure 1 illustrates the timing of the model.

3 The deposit contract and bank runs

In this section we derive the optimal deposit contract $c_t = \{c_1, c_2\}$, in the absence of deposit insurance and investors.

Suppose that all consumers deposit their endowments in banks. Banks can invest $f = \gamma c_1$ in storage which provides one unit at $t = 1$ and $1 - f$ in asset A which provides a higher expected return at $t = 2$ than the storage technology.

In the high-return state, the return on the deposits left in banks per depositor from $t = 1$ to $t = 2$ is $(1 - \gamma c_1) R_h^A$. For a given c_1, the feasible c_2 per patient depositor is

$$c_{2h}^A = \left(\frac{1 - \gamma c_1}{1 - \gamma} \right) R_h^A \tag{9}$$

Incentive compatibility requires that $c_1 \leq c_{2h}^A$, because otherwise all patient depositors will withdraw at $t = 1$, in which case the equilibrium is not feasible. The increase in utility due to consumption at or above the threshold r is sufficiently large that it compensates for the lower return from liquidating asset A at $t = 1$. This requires

Assumption 3:

$$\frac{r+\pi}{r} > R_h^A$$

This condition is sufficient for banks to be able to provide consumption smoothing. The left hand side says that the utility gain in terms of consumption $(\pi + r)$ of consuming r for the impatient agent is greater than the gross return (R_h^A) of investing one unit in risky asset A.[4] This requires that the utility loss from $c_1 < r$ be sufficiently large that it pays to provide r at $t = 1$. Under these conditions, depositors will pay for insurance of consumption r at $t = 1$ by accepting lower consumption at $t = 2$. As shown in the Appendix, if $\frac{r+\pi}{r} \leq R_h^A$, banks would provide a contract with payoffs to impatient depositors of zero at $t = 1$ in the high state and $\frac{R_h^A}{1-\gamma}$ to patient depositors.

In the low-return state, asset A has a return of R_ℓ^A. If patient consumers receive r, then the feasible second period consumption per patient consumer is

$$c_{2\ell}^A = \left(\frac{1-\gamma c_1}{1-\gamma}\right) R_\ell^A. \tag{10}$$

If $c_1 > 1$ and $R_\ell^A = 1$, then $c_{2\ell}^A < c_1$.[5]

Because second-period consumption is less than first-period consumption and type is private information, the equilibrium in the low-return state is a run at $t = 1$ with all consumption equal to one. At $t = 1$ depositors receive a perfect signal regarding the state. If $c_1 \geq r > 1$, a type-2 depositor will always withdraw in the low state because $c_{2\ell}^A < c_1$. We focus on fundamental bank runs, i.e., bank runs based on low returns on assets in which the

[4] The Appendix provides the demonstration.

[5] Consumption by patient depositors at $t = 2$ is less than consumption at $t = 1$ because $1 - \gamma c_1$ is less than $1 - \gamma$ when c_1 is greater than one.

necessary and sufficient condition for a bank run is that the incentive constraint is violated. We rule out pure panic runs of the Diamond and Dybvig type.[6]

As shown in the Appendix, the optimal contract implies setting $c_1 = r$. This follows because the expected return from asset A is strictly higher than the expected return from the storage technology used to finance consumption at $t = 1$ and depositors are risk neutral.

The expected utility of depositors with this contract is higher than expected utility with autarky and also is higher than the expected utility from investing in asset B.

This leads to the following proposition:

Proposition 1 *When there is no deposit insurance and π is high enough to make consumption smoothing optimal, banks invest in asset A and offer the following contract: $c_1 = r$ and $c_{2h} = \left(\frac{1-\gamma c_1}{1-\gamma}\right) R_h^A$ in asset A's high state. In the bad state, there is a bank run, the bank is liquidated and all depositors receive the same payoff of $c_{1\ell} = 1$ at $t = 1$. The expected utility of depositors is:*[7]

$$\mathrm{E}\, U^A = p^A[\gamma r + (1-\gamma)c_{2h}^A] + (1-p^A)[1-\gamma\pi] \tag{11}$$

Proof: See the Appendix.

4 Capital

We introduce a third group of agents in the economy. They have a risk-neutral utility function unaffected by liquidity,

$$U_k = c_1 + c_2 \tag{12}$$

[6]Allen and Gale (2007) have a nice discussion of this issue.

[7]The utility when there is a run is $(1-p^A)[\gamma(1-\pi) + (1-\gamma)] = (1-p^A)(1-\gamma\pi)$.

We call these agents "investors". We assume there is an infinite supply of capital with an opportunity cost ρ greater or equal to the expected return on asset A, so

$$\rho \geq \mathrm{E}\, R^A. \tag{13}$$

These investors receive dividends from the bank at $t = 2$ if there are funds left after paying depositors. Investors are competitive and their dividend, (d_2^A), when the bank invests in asset A, is such that the expected dividend at $t = 2$ equals their opportunity cost, that is

$$p^A d_2^{AH} + (1 - p^A) d_2^{AL} = \rho k \tag{14}$$

where d_2^{AH} is the dividend paid in the high state, d_2^{AL} is the dividend paid in the low one and k is the amount of capital at the bank.

The purpose of this section is to see under which conditions banks would be willing to have capital without regulation. Given that capital is costly, the only motivation in our model to have capital is to prevent runs in the bad state. Suppose that banks find it optimal to issue enough capital to avoid bank runs. We will later on determine the conditions for this to be an equilibrium. Bank runs can be avoided with asset A in the low-return state if the following incentive compatibility constraint is satisfied

$$c_{2\ell}^{Ak} = \frac{1 + k - \gamma r - d_2^{AL}}{1 - \gamma} \geq r \tag{15}$$

which simplifies to

$$1 + k \geq r + d_2^{AL} \tag{16}$$

If in equilibrium the above condition holds, capital can be used to avoid bank runs when the bank invests in asset A. Given that capital is costly, the incentive compatibility constraint will always hold with equality. Additionally, dividends will never be paid in the low state.[8]

[8]Note that the dividend in the low state of nature has to fulfill condition (16). Consequently, by increasing

Expected utility with asset A with investors is

$$\mathrm{E}\,U^{Ak} = p^A[\gamma r + (1-\gamma)c_{2h}^{Ak}] + (1-p^A)c_{2\ell}^{Ak} \tag{17}$$

where

$$c_{2h}^{Ak} = \frac{(1+k-\gamma r)R_h^A - d_2^{AH}}{(1-\gamma)} \tag{18}$$

is the second period consumption when the bank invests in asset A. This can be rewritten as

$$c_{2h}^{Ak} = c_{2h}^{A} + \frac{kR_h^A - d_2^{AH}}{(1-\gamma)} \tag{19}$$

To avoid bank runs in the high state, it must be the case that

$$c_1 \leq c_{2h}^{Ak} \tag{20}$$

because otherwise all patient depositors will withdraw at $t = 1$, in which case the equilibrium is not feasible.[9]

If the bank invests in asset B, there is a run with probability $(1 - p^B)$ and the bank is liquidated. The available resources from storage (γr) are distributed equally among agents, and impatient depositors will suffer the utility loss, because their consumption is less than r.[10] Expected utility with asset B and investors is

$$\mathrm{E}\,U^{Bk} = p^B[\gamma r + (1-\gamma)c_{2h}^{Bk}] + (1-p^B)\gamma[r-\pi] \tag{21}$$

where

$$c_{2h}^{Bk} = \frac{(1+k-\gamma r)R^B - d_2^{B}}{(1-\gamma)} \tag{22}$$

d_2^{AL} we have to increase k by the same amount, and there is an opportunity cost of ρ. Therefore, banks will try to limit k to the minimum while avoiding bank runs. On the other hand, the expected return of investors just satisfies equation (14) and d_2^L=0.

[9]This inequality can be written as $R_h^A \geq \frac{r(1-\gamma)+d_2^{AH}}{1+k-\gamma r}$

[10]The utility when there is a run is $(1-p^B)[\gamma(\gamma r - \pi) + (1-\gamma)\gamma r] = (1-p^B)\gamma[r-\pi]$.

is the second period consumption when the bank invests in asset B. This can be written

$$c_{2h}^{Bk} = c_{2h}^{B} + \frac{kR^B - d_2^B}{(1-\gamma)} \tag{23}$$

where d_2^B is the dividend payment when the bank invests in asset B. The expected dividend payment equals the opportunity cost and so $d_2^B = \frac{\rho k}{p^B}$.

As before, incentive compatibility and no run requires that[11]

$$c_1 \leq c_{2h}^{Bk} \tag{24}$$

The main result of this section is provided in the following proposition:

Proposition 2 *If the benefits that are obtained when banks issue capital (impatient agents do not suffer the utility loss) exceed the cost of capitalizing banks (additional cost of using capital instead of deposits) that is,*

$$\pi\gamma(1-p^A) \geq k[\rho - p^A R_h^A - (1-p^A)] \tag{25}$$

there are no runs and no holdings of asset B in equilibrium.

Proof: We first have to check under which conditions the expected utility of investing in asset A is at least as high as investing in asset B, that is, $\mathrm{E}\,U^{Ak} \geq \mathrm{E}\,U^{Bk}$. Written out, this is the condition that

$$p^A[\gamma r + (1-\gamma)c_{2h}^{Ak}] + (1-p^A)(\gamma r + (1-\gamma)c_{2\ell}^{Ak} \geq p^B[\gamma r + (1-\gamma)c_{2h}^{Bk}] + (1-p^B)\gamma[r-\pi] \tag{26}$$

[11] This inequality can be written as $R^B \geq \frac{r(1-\gamma)+d_2^B}{1+k-\gamma r}$

Making use of equations (16), (19) and (23), the above equation is equivalent to

$$p^A[\gamma r+(1-\gamma)c_{2h}^A+kR_h^A-d_2^{AH}]+(1-p^A)(1+k) \geq p^B[\gamma r+(1-\gamma)c_{2h}^B+kR^B]-\rho k+(1-p^B)\gamma[r-\pi] \tag{27}$$

Assumption 2 implies that

$$p^A[\gamma r + (1-\gamma)c_{2h}^A] + (1-p^A) \geq p^B[\gamma r + (1-\gamma)c_{2h}^B] \tag{28}$$

Consequently, a sufficient condition for the bank to invest in asset A is

$$k(p^A R_h^A + (1-p^A) - p^B R^B) \geq (1-p^B)\gamma[r-\pi] \tag{29}$$

This condition says that the gain obtained from investing in asset A instead of B has to outweigh the cost of the run that takes place with asset B. Notice that in this case, when the asset fails with probability $1 - p_B$, impatient depositors suffer the utility loss.

Because the expected return on both assets is the same, the above condition simplifies to:

$$0 \geq (1-p^B)\gamma[r-\pi]. \tag{30}$$

This implies that a sufficient condition is that $r < \pi$, that is the liquidity loss is higher than r.

Finally, the equilibrium with capital is indeed an equilibrium if the expected utility achieved with capital ($\mathrm{E}\,U^{Ak}$) is higher than the utility achieved in the economy without capital ($\mathrm{E}\,U^A$), i.e.,

$$p^A[\gamma r+(1-\gamma)c_{2h}^{Ak}]+(1-p^A)(1+k) \geq p^A[\gamma r+(1-\gamma)c_{2h}^A]+(1-p^A)[\gamma(1-\pi)+(1-\gamma)] \tag{31}$$

Substituting the value of c_{2h}^{Ak} given by equation (19) results in

$$p^A\left[\gamma r + (1-\gamma)\left(c_{2h}^A + \frac{kR_h^A - \frac{\rho k}{p_A}}{(1-\gamma)}\right)\right] + (1-p^A)(1+k) \geq \tag{32}$$

$$p^A[\gamma r + (1-\gamma)c_{2h}^A] + (1-p^A)[\gamma(1-\pi) + (1-\gamma)] \tag{33}$$

After simplification of the terms γr and c_{2h}^A on both sides we have

$$p^A kR_h^A - \rho k + (1-p^A)(1+k) \geq (1-p^A)[\gamma(1-\pi) + (1-\gamma)] \tag{34}$$

Taking k common factor on the left hand side and simplifying the right hand side

$$k[(p^A R_h^A - \rho + (1-p^A)] + (1-p^A) \geq (1-p^A)(1-\gamma\pi) \tag{35}$$

or

$$k[(p^A R_h^A - \rho + (1-p^A)] \geq (1-p^A)(1-\gamma\pi) - (1-p^A) \tag{36}$$

which becomes

$$k[(p^A R_h^A - \rho + (1-p^A)] \geq -(1-p^A)\gamma\pi \tag{37}$$

If we multiply both sides by (-1) we have

$$k[(-p^A R_h^A + \rho - (1-p^A)] \leq (1-p^A)\gamma\pi \tag{38}$$

or

$$\pi\gamma(1-p^A) \geq k[\rho - p^A R_h^A - (1-p^A)] \tag{39}$$

Q.E.D

Note that he left hand side is the benefit of the insurance provided by capital, that is, impatient depositors do not longer suffer the utility loss associated to the bank run (note that in the absence of capital, when banks invest in the safer asset A, there is a bank run with probability $(1 - p_A)$ and impatient depositors, γ, will suffer the utility lose π). The right hand side of the equation is the "cost of providing insurance though capital" since it refers to the additional cost of using capital instead of deposits. Capital (k) costs ρ, while investing those funds in the bank will only provide $p^A R_h^A + (1 - p^A)$.

Consequently, if the benefits provided by raising capital are higher than its costs, then capital will appear endogenously in this model.

5 Deposit Insurance

In the previous section we saw that capital could resolve endogenously the risk created by bank runs and financial crises. Nevertheless, there are different reasons that could explain why the regulator might prefer to introduce a deposit insurance system before the market raises the optimal level of capital that prevents those runs. This section introduces a deposit insurance system, similar to those operated by governments in many countries (see Demirgüç-Kunt et al. 2014), which guarantees at least the amount promised by the bank $c_1 = r$ at $t = 1$ and so impatient depositors do not suffer the utility loss. The banks pay an ex-ante fixed premium τ to the insurance fund, and second period resources at the bank are $(1 - \tau - \gamma r)$ after impatient depositors receive r. We assume that the premium paid ex ante by banks, τ is sufficiently high that it covers expected losses at the bank.

With deposit insurance, the expected utility of investing in asset B is greater than or equal to the expected utility from investing in asset A. This is not surprising. Asset B has a higher payoff in the high state and a lower payoff in the low state than asset A. With deposit insurance, the lower payoff in the low state is irrelevant to depositors, which makes asset B preferable.

This result is summarized in the following proposition:

Proposition 3 *Deposit insurance introduces a moral hazard problem, as in this case, it is optimal to invest in the riskier asset B.*

Proof: With deposit insurance, the expected utility with asset A is $\mathrm{E}\, U^{Ai}$ which equals

$$\mathrm{E}\, U^{Ai} = p^A[\gamma r + (1-\gamma)c_{2h}^{Ai}] + (1-p^A)r \tag{40}$$

and

$$c_{2h}^{Ai} = \frac{(1-\tau-\gamma r)R_h^A}{(1-\gamma)}. \tag{41}$$

is the second period consumption when the bank invests in asset A. Expected utility with asset B is

$$\mathrm{E}\, U^{Bi} = p^B[\gamma r + (1-\gamma)c_{2h}^{Bi}] + (1-p^B)r \tag{42}$$

where

$$c_{2h}^{Bi} = \frac{(1-\tau-\gamma r)R^B}{(1-\gamma)} \tag{43}$$

is the second period consumption when the bank invests in asset B.

The expected utility of investing in asset A is less than or equal to the expected utility from investing in asset B, that is, $\mathrm{E}\, U^{Ai} \leq \mathrm{E}\, U^{Bi}$ which is

$$p^A[\gamma r + (1-\gamma)c_{2h}^{Ai}] + (1-p^A)r \leq p^B[\gamma r + (1-\gamma)c_{2h}^{Bi}] + (1-p^B)r \tag{44}$$

This equation can be rewritten

$$(p^A - p^B)\gamma r + p^A[(1-\gamma)c_{2h}^{Ai}] \leq (p^A - p^B)r + p^B[(1-\gamma)c_{2h}^{Bi}] \tag{45}$$

We take the equation by pieces. Because $\gamma < 1$,

$$(p^A - p^B)\gamma r \leq (p^A - p^B)r. \tag{46}$$

The remaining term is

$$p^A[(1-\gamma)c_{2h}^{Ai}] \leq p^B[(1-\gamma)c_{2h}^{Bi}] \tag{47}$$

Making use of equations (41) and (43), equation (47) can be written as

$$p^A[(1-\tau-\gamma r)R_h^A] \leq p^B[(1-\tau-\gamma r)R^B] \tag{48}$$

which with if $(1-\tau-\gamma r) > 0$ simplifies to

$$p^A R_h^A \leq p^B R^B \tag{49}$$

This last condition is automatically satisfied by assumption 2. Q.E.D

6 Capital and Insurance

The purpose of this section is to examine whether capital regulation can prevent the moral hazard problem that arises because of deposit insurance. Assume the regulator sets a capital requirement at a level $\bar{k}$, which implies that available resources to invest in asset A or B are $1-\tau+\bar{k}-\gamma r$.

The values of second-period consumption are used in this proof of the proposition below. Depositors' second period consumption in the high state with asset A is obtained from the second period constraint

$$c_{2h}^{Ak} = \frac{(1-\tau+\bar{k}-\gamma r)R_h^A - d_2^{AH}}{(1-\gamma)} \tag{50}$$

which can also be expressed as a function of c_{2h}^{Ai}, given by (41):

$$c_{2h}^{Aki} = c_{2h}^{Ai} + \frac{\bar{k}R_h^A - d_2^{AH}}{(1-\gamma)}. \tag{51}$$

If the bank invests in asset B, depositors' second period consumption in the high state is

$$c_{2h}^{Bki} = \frac{(1-\tau+\bar{k}-\gamma r)R^B - d_2^B}{(1-\gamma)} \tag{52}$$

Expressed as a function of c_{2h}^{Bi} from (43), this is

$$c_{2h}^{Bki} = c_{2h}^{Bi} + \frac{\bar{k}R^B - d_2^B}{(1-\gamma)} \tag{53}$$

The result of this section is summarized in the following proposition:

Proposition 4 *In the presence of deposit insurance, capital requirements are ineffective in preventing moral hazard; banks invest in asset B. We show this with a proof by contradiction.*

Proof: in order for required capital to eliminate the moral hazard problem with deposit insurance, the expected utility when the bank invests in asset A is at least as high as when it invests in asset B, that is, $\mathrm{E}\,U^{Aki} \geq \mathrm{E}\,U^{Bki}$. This requires

$$p^A[\gamma r + (1-\gamma)c_{2h}^{Aki}] + (1-p^A)r \geq p^B[\gamma r + (1-\gamma)c_{2h}^{Bki}] + (1-p^B)r \tag{54}$$

Substituting the values given by (51) and (53) yields

$$p^A[\gamma r+(1-\gamma)c_{2h}^{Ai}]+(1-p^A)r+p^A\overline{k}R_h^A-k\rho \geq p^B[\gamma r+(1-\gamma)c_{2h}^{Bi}]+(1-p^B)r+p^B\overline{k}R^B-k\rho \tag{55}$$

This condition can be rewritten

$$(p^A - p^B)\gamma r + p^A(1-\gamma)c_{2h}^{Ai} + p^A\overline{k}R_h^A \geq (p^A - p^B)r + p^B(1-\gamma)c_{2h}^{Bi} + p^B\overline{k}R^B \tag{56}$$

This condition is never satisfied. First, as shown in the previous section, equation (45) always holds, i.e.,

$$(p^A - p^B)\gamma r + p^A(1-\gamma)c_{2h}^{Ai} \leq (p^A - p^B)r + p^B(1-\gamma)c_{2h}^{Bi} \tag{57}$$

Then, for the Equation (56) to hold, it is necessary that

$$p^A R_h^A \geq p^B R^B \tag{58}$$

which is ruled out by assumption 2. Q.E.D

7 Surety and Insurance

This section shows how a policy of a surety bond combined with capital requirements can resolve the moral hazard problem. The government requires investors to post a surety bond which is used to pay depositors if the bank fails.

In particular, banks are required to post an amount s into a surety bond that pays $R^S s$ in case of success, where R^S is the return on the bond. In this case, the investment in the long-term asset equals total assets $1 + k$ less the deposit insurance premium, τ and the investment in the short-term asset to satisfy impatient depositors.

We assume that outside resources are not required in addition to the insurance fund and the surety bond. This implies that the deposit insurance premium paid ex ante by banks, τ, plus the resources provided by the surety, $R^S s$, must be sufficiently high to cover losses at the bank. That is, if the bank invests in asset A then:

$$\tau + sR^S(1 - p^A) \geq [r - (1 + k - \tau)](1 - p^A) \tag{59}$$

In case of the bank's failure, investors receive any remaining funds:

$$\max(\tau + sR^S(1 - p^A) - [r - (1 - \tau)](1 - p^A), 0) \tag{60}$$

Can the surety bond resolve the moral hazard problem? With the surety bond, the expected utility with asset A is

$$\mathrm{E}\, U^{As} = p^A[\gamma r + (1 - \gamma)c_{2h}^{As}] + (1 - p^A)r \tag{61}$$

Consumption in the second period in the high state when the bank invests in asset A is given by

$$c_{2h}^{As} = \left(\frac{(1+k-\tau-\gamma r)R_h^A - d_2^{AHs}}{1-\gamma} \right) \tag{62}$$

and the dividend in the high state is derived from the incentive compatibility condition:

$$p^A(d_2^{AHs} + sR^S) + (1-p^A)\max(\tau + sR^S(1-p^A) - [r-(1+k-\tau)](1-p^A), 0) \geq \rho(k+s) \tag{63}$$

In the high state, investors receive two types of returns, those in the form of dividends and those from the surety bond which pays investors as long as the bank is solvent. Investors' expected return must be greater than or equal to their opportunity cost ρ.

Expected utility with asset B is

$$\mathrm{E}\, U^{Bs} = p^B[\gamma r + (1-\gamma)c_{2h}^{Bs}] + (1-p^B)r \tag{64}$$

Consumption in the second period in the high state when the bank invests in asset B is given by

$$c_{2h}^{Bs} = \left(\frac{(1+k-\tau-\gamma r)R^B - d_2^{Bs}}{1-\gamma} \right) \tag{65}$$

and the dividend in the high state is derived from the incentive compatibility condition

$$p^B(d_2^B + sR^S) \geq \rho(k+s) \tag{66}$$

Requiring investors to post a surety bond s and capital k can prevent moral hazard at banks due to deposit insurance. This result is summarized in the following proposition:

Proposition 5 *For a given level of capital k, a policy of requiring banks to post an amount $s \geq s^\star$ in a surety bond can prevent the moral hazard problem generated by deposit insurance. The level $s^\star$ is given by*

$$s^\star = \frac{(1+k-\tau-\gamma r)(p^B R^B - p^A R^A) + (p^B - p^A)\gamma r + (p^A - p^B)r}{(p^A - p^B)R^S} \tag{67}$$

Proof: Solving the moral hazard problem requires that $\mathrm{E}\, U^{As} \geq \mathrm{E}\, U^{Bs}$ which can be written out as

$$p^A[\gamma r + (1-\gamma)c_{2h}^{As}] + (1-p^A)r \geq p^B[\gamma r + (1-\gamma)c_{2h}^{Bs}] + (1-p^B)r. \tag{68}$$

Making use of equations (62) and (65), the above condition can be rewritten:

$$p^A[\gamma r+(1+k-\tau-\gamma r)R_h^A+sR^S-\rho k/p^A]-p^A r \geq p^B[\gamma r+(1+k-\tau-\gamma r)R^B+sR^S-\rho k/p^B]-p^B r. \tag{69}$$

This can be written as

$$(p^A - p^B)[r(\gamma-1) + sR^S] \geq (1+k-\tau-\gamma r)(p^B R^B - p^A R^A) \tag{70}$$

The left-hand side of the equation represents the net gain from investing in asset A instead of B and it has two components: the first part is the net saving for the regulator since it has to pay $r(1-\gamma)$ in the bad state with a lower probability. The second component represents the additional return received by investors from the surety bond. The right hand side of the inequality represents the additional returns from investing in the riskier asset B instead of asset A. Solving for s, we obtain that s (the proportion invested in the surety bond) should be greater or equal to $s^\star$ in order to guarantee that banks will choose project A instead of project B, where

$$s \geq s^\star = \frac{(1+k-\tau-\gamma r)(p^B R^B - p^A R^A) + (p^B - p^A)\gamma r + (p^A - p^B)r}{(p^A - p^B)R^S} \tag{71}$$

Q.E.D

As before, incentive compatibility requires that[12]

$$c_1 \leq c_{2h}^{AS} \tag{72}$$

[12]This inequality can be written as $R_h^A \geq \frac{r(1-\gamma)+d_2^{AHs}}{1+k-\tau-\gamma r}$

The surety bond, capital and deposit insurance can provide higher utility than the competitive equilibrium with no insurance or capital. This requires comparing $\mathrm{E}\,U^{As}$ to $\mathrm{E}\,U^{A}$, i.e.

$$p^A[\gamma r + (1-\gamma)c_{2h}^{As}] + (1-p^A)r \geq p^A[\gamma r + (1-\gamma)c_{2h}^{A}] + (1-p^A)[\gamma(1-\pi) + (1-\gamma)] \quad (73)$$

Substituting the value of c_{2h}^{As} given by equation (62) and c_{2h}^{A} given by (9), we have:

$$p^A[\gamma r+(1+k-\tau-\gamma r)R_h^A+sR^S-\rho(k+s)/p^A]+(1-p^A)r \geq p^A[\gamma r+(1-\gamma r)R_h^A]+(1-p^A)(1-\gamma\pi) \quad (74)$$

This can be rewritten as

$$p^A[sR^S + kR_h^A] + (1-p^A)(r-1+\gamma\pi) \geq \rho(k+s) + \tau p^A R_h^A \quad (75)$$

The above equation indicates that the additional benefits produced with a surety bond policy (in combination with deposit insurance and capital) are higher than its costs. The expected benefitis he sum of the returns from the surety bond and capital, $sR^S + kR_h^A$ received with probability p^A and the benefits associated with deposit insurance (impatient consumers no longer suffer the utility loss, as they consume r instead of 1) received with probability $(1-p^A)$. The right side side represents the costs of these policies, i.e the cost of capital and the opportunity cost of deposit insurance. If this equation is satisfied and the conditions implied by Proposition 5 hold – banks put an amount in the surety greater or equal to $s^\star$ – the surety bond policy yields higher expected utility and banks invest in the safer asset A.

In the following we provide a numerical example. The basic parameters used in the simulations are shown in the following table:

We can check that for these parameters, both assets yield an expected return of 1.27. The amount that should be put in the surety, in order to avoid moral hazard, should be

π	R_A	p_A	R_B	p_B	r	γ	k	ρ	R_s
1.20	1.30	0.90	1.70	0.74	1.01	0.60	0.08	1.28	1.26

Table 1: Parameters

Parameters	$s^\star$
1. $p_B R_B$	$+$
2. $p_A R_A$	$-$
3. R_s	$-$
4. γ	$-$
5. k	$+$

Table 2: Comparative Statics

higher than 34 per cent of total assets.

Table 2 shows how $s^\star$ is affected by different parameters of the model, as asset B's return in the high state, asset A's return in the high state, the return on the surety, the proportion of impatient depositors and the level of capital. As expected, a higher expected return of asset B (considering only the high state) will make moral hazard more likely and consequently the regulator will require a higher investment on the surety bond to reduce such behavior. On the other hand, a higher expected return of the safer asset (considering only the high state) will reduce the size of the bond. A higher expected return on the surety bond will reduce the necessary funds to be invested in the bond to prevent moral hazard. In the same way, a higher proportion of impatient agents proportionally reduces the funds available to invest in the long term investment and reduce the incentive for moral hazard and thus reduce the importance of the surety bond. Finally, if the level of capital increases the amount to be put in the surety also increases.

To conclude this section we analyze the case where the amount put in the surety bond is less than $s^\star$. In this case, we know that banks would invest in asset B, as the expected utility is higher than that of investing in asset A (see Proposition 5). We can compare this case to the competitive equilibrium with bank runs. This requires comparing $\mathrm{E}\,U^{Bs}$ to $\mathrm{E}\,U^{A}$, i.e.

$$p^B[\gamma r + (1-\gamma)c_{2h}^{Bs}] + (1-p^B)r \geq p^A[\gamma r + (1-\gamma)c_{2h}^{A}] + (1-p^A)[\gamma(1-\pi) + (1-\gamma)] \quad (76)$$

Substituting the value of c_{2h}^{Bs} given by equation (65) and c_{2h}^{A} given by (9), we have:

$$p^B[\gamma r+(1+k-\tau-\gamma r)R^B+sR^S-\rho(k+s)/p^B]+(1-p^B)r \geq p^A[\gamma r+(1-\gamma r)R_h^A]+(1-p^A)(1-\gamma\pi) \quad (77)$$

Making use of equation (6):

$$p^B[\gamma r + (k-\tau)R^B + sR^S] + (1-p^B)r - \rho(k+s) \geq p^A\gamma r + (1-p^A)\gamma(r-\pi) \quad (78)$$

or,

$$p^B[(k-\tau)R^B + sR^S] + (1-p^B)(1-\gamma)r - \rho(k+s) \geq (1-p^A)\gamma(-\pi) \quad (79)$$

The left hand side represents the additional benefits of intervention minus its costs. On the right hand side the costs of bank runs.

Again, we assume that the premium paid ex ante by banks, τ, plus the resources provided by the surety, R^S, with $s < s^\star$, are sufficiently high that they cover losses at the bank. If the bank invests in asset B, $\tau + sR^S(1-p^B) = \gamma(r-\pi)(1-p^B)$. Hence, outside resources are not required in addition to the insurance fund and the surety bond, otherwise, the government would allow bank runs to happen.

8 Conclusion

In this paper we show that capital can avoid bank runs only when the opportunity cost of capital is low and in the absence of deposit insurance. Without deposit insurance, capital can arise endogenously and create a welfare improving equilibrium relative to an equilibrium with bank runs and no capital. We then analyze deposit insurance as an alternative and show how moral hazard will arise. We show that capital requirements alone cannot prevent moral hazard when deposit insurance is introduced into this model.

We show that a surety bond can be an efficient policy to solve the moral hazard problem due to deposit insurance. A surety bond can create charter value but does not require restrictions on competition to generate the rents. The surety bond requires banks to set aside funds that are invested in marketable securities and that would be used by bank regulators to pay off the banks' liabilities in case of bank failure. Bank stockholders receive their opportunity cost on those funds while the bank is in business. If the bank fails, the surety bond can be used to pay losses suffered by depositors in addition to deposit insurance. Investors receive the value of any remaining surety bond once depositors are paid off.

These results open up several directions for future research. In what assets should the bond be invested and how might different investments affect banks' behavior? If all the funds are invested in Treasury securities, a bank might be inclined to hold a riskier portfolio in its banking business. What is a good way to require that investors add to the bond when the bank becomes larger? Having a bond that is a fraction of assets would be necessary for it to be equally effective and feasible for small and large banks. This would affect the lump-sum aspect of the surety bond. The design of additions is very important to continue the lump-sum aspect of the surety-bond which requires additions over time.

Appendix

We first compare the return maximizing contract to autarky using asset A. We compare the high return state and then the low-return state.

In the high return state, autarky provides one unit of consumption at $t = 1$ to a depositor who turns out to be impatient and R_h^A units of consumption at $t = 2$ to a depositor who turns out to be patient.

The return maximizing contract invests all the deposits in asset A and keeps the funds invested until $t = 2$. A bank can do this and provides zero at $t = 1$ and pays out R_h^A at $t = 2$ in the high-return state for each unit invested.[13] There is no reason to pay anything to impatient depositors because their utility from consumption at $t = 2$ is zero. The contract which maximizes the return conditional on being in the high state pays $R_h^A / (1 - \gamma)$ to each patient depositor. The bank can pay more than R_h^A to each patient depositor because there are only $1 - \gamma$ patient depositors. The γ early consumers receive zero consumption at $t = 1$ and receive utility $-\pi$, while the $(1 - \gamma)$ late consumers receive $R_h^A / (1 - \gamma)$ at $t = 2$.

The expected utility of the payoffs in the high state in autarky $\left(1, R_h^A\right)$ is

$$\mathrm{E}\left[U(1)|h\right] = \gamma(1 - \pi) + (1 - \gamma)R_h^A. \tag{80}$$

The expected utility in the high state of the return maximizing bank contract $\left(0, \frac{R_h^A}{1-\gamma}\right)$ is

$$\mathrm{E}\left[U(2)|h\right] = \gamma(0 - \pi) + (1 - \gamma)\frac{R_h^A}{1 - \gamma} = R_h^A - \gamma\pi. \tag{81}$$

$\mathrm{E}\left[U(2)|h\right]$ is necessarily greater than $\mathrm{E}\left[U(1)|h\right]$. $\mathrm{E}\left[U(2)|h\right] \geq \mathrm{E}\left[U(1)|h\right]$ is equivalent to

$$R_h^A - \gamma\pi \geq \gamma(1 - \pi) + (1 - \gamma)R_h^A \tag{82}$$

Eliminating $\gamma\pi$ from both sides yields

$$R_h^A \geq \gamma + (1 - \gamma)R_h^A. \tag{83}$$

Solving for R_h^A yields

$$R_h^A \geq 1 \tag{84}$$

which is satisfied by assumption.

In the low state, autarky provides $(1, 1)$ and the income-maximizing contract provides

[13] Given the preferences in equations (1) and (2), this is equivalent to maximizing expected utility if π equaled zero in the utility function.

$\left(0, \frac{1}{1-\gamma}\right)$ but these different payoffs yield the same expected utility. The expected utility of the payoff in autarky is

$$\mathrm{E}\left[U(1)|\ell\right] = \gamma(1-\pi) + (1-\gamma) = 1 - \gamma\pi. \tag{85}$$

The expected utility of the income-maximizing payoff is

$$\mathrm{E}\left[U(2)|\ell\right] = \gamma(0-\pi) + (1-\gamma)\frac{1}{1-\gamma} = 1 - \gamma\pi. \tag{86}$$

Hence, expected utility in the low state is the same for both autarky and the income-maximizing contract.

The results for the high and low states combined imply that the return maximizing bank contract $\left(0, \frac{\mathrm{E}\,R^A}{1-\gamma}\right)$ dominates autarky $\left(1, \mathrm{E}\,R^A\right)$. This of course does not imply it always is the optimal contract.

If the utility loss from consumption below the threshold r is sufficiently large, depositors prefer an income-smoothing contract offering $\left(r, \mathrm{E}\,c_2^A\right)$ to the expected-return maximizing contract $\left(0, \frac{\mathrm{E}\,R^A}{1-\gamma}\right)$. We can confine attention to the high state. In the low state, as other assumptions about banking and runs imply, the sharing contract pays one unit to each depositor. We already have seen that the expected-return maximizing contract has the same expected utility as such a contract. Hence, utility in the high state determines the ranking of the return-maximizing contract and an income-smoothing contract.

In the high state, the income-sharing contract considered pays r in the first period and the implied residual c_{2h}^A in the second period. With $c_1 = r$, consumption at $t = 2$ in the high state is

$$c_{2h}^A = \left(\frac{1-\gamma r}{1-\gamma}\right) R_h^A \tag{87}$$

The expected utility of the income-smoothing contract in the high state $\mathrm{E}[U(3)|h]$ is

$$\mathrm{E}[U(3)|h] = \gamma r + (1-\gamma)\left(\frac{1-\gamma r}{1-\gamma}\right) R_h^A = \gamma r + (1-\gamma r) R_h^A \tag{88}$$

The expected utility of the return-smoothing contract $\mathrm{E}[U(3)|h]$ is higher than the expected utility of the expected-return maximizing contract in the high state if

$$\gamma r + (1-\gamma r) R_h^A \geq R_h^A - \gamma\pi. \tag{89}$$

This is equivalent to

$$\pi > r(R_h^A - 1) \tag{90}$$

or

$$\frac{\pi}{r} \geq \frac{(R_h^A - 1)}{1} \tag{91}$$

which we assume is satisfied. If it were not, there would be no income smoothing with the associated bank runs. As the text discusses, it basically is a condition that π – the utility loss due to consumption less than r – has to be large enough that income smoothing dominates maximizing the expected return. This is presented in the text as equation (3).

This analysis implies that the optimal contract has $c_1 \geq r$.

Consumption such that $c_1 > r$ is not optimal for two reasons. The higher first-period consumption, the less is invested in the long-term asset A. The less invested in the long-term asset A, the lower expected income per depositor. Depositors are risk neutral other than the liquidity requirement π. Absent the π term, all investment would be in the long-term asset. With the π term in the utility function, only enough will be withdrawn at $t = 1$ to satisfy impatient depositors and get first-period consumption up to the discontinuity in the utility function.

Hence, $c_1 = r$ in the high state. To avoid bank runs in the high state, the following condition must hold

$$c_{2h}^{A} \geq c_1 = r \tag{92}$$

and this inequality can be written

$$R_h^A \geq \frac{r(1-\gamma)}{(1-\gamma r)} \tag{93}$$

Finally, we need to prove that $\mathrm{E}\,U^A \geq \mathrm{E}\,U^B$ given the bank contract. The expected utility from investing in the return-sharing bank contract is

$$\mathrm{E}\,U(3) = p^A\left[\gamma r + (1-\gamma r)\,R_h^A\right] + \left(1-p^A\right)\left[1-\gamma\pi\right]. \tag{94}$$

Asset B in the low-return state yields zero at $t = 1$ and zero at $t = 2$. It yields $R^B > R_h^A$ in a high-return state with probability p^B. Consumption in the high return state with asset B by impatient depositors is r and consumption by patient depositors is

$$c_{2h}^{B} = \left(\frac{1-\gamma r}{1-\gamma}\right) R^B. \tag{95}$$

Consumption promised in the low return state with asset B to impatient depositors is r and we assume sufficient storage asset is held to pay this. In the bad state though, there would be a run and all depositors would receive the same fraction of r, which implies that the return per depositor is γr. The expected utility in the low state is

$$\mathrm{E}\left[U(4)|\ell\right] = \gamma\left(r\gamma - \pi\right) + (1-\gamma)\left(r\gamma\right) = \gamma\left(r - \pi\right) \tag{96}$$

The expected utility from investing in asset B with the promised return r at $t = 1$ is

$$\mathrm{E}\,U(4) = p^B\left[\gamma r + (1-\gamma r)\,R^B\right] + \left(1-p^B\right)\left[\gamma\left(r-\pi\right)\right] \tag{97}$$

$\mathrm{E}\,U(3) \geq \mathrm{E}\,U(4)$ if

$$p^A\left[\gamma r + (1-\gamma r)\,R_h^A\right] + \left(1-p^A\right)[1-\gamma\pi] \\ \geq \\ p^B\left[\gamma r + (1-\gamma r)\,R^B\right] + \left(1-p^B\right)[\gamma\,(r-\pi)] \tag{98}$$

Let 1-$\gamma\pi = \gamma r + 1 - \gamma r - \gamma\pi$ and replace it above to obtain

$$\gamma r + p^A(1-\gamma r)R_h^A + (1-p^A)[(1-\gamma r-\gamma\pi)] \geq \gamma r + p^B[(1-\gamma r)R^B] + (1-p^B)\gamma[-\pi]. \tag{99}$$

Canceling γr on both sides yields

$$p^A(1-\gamma r)R_h^A + (1-p^A)[(1-\gamma r-\gamma\pi)] \geq p^B[(1-\gamma r)R^B] + (1-p^B)\gamma[-\pi] \tag{100}$$

which can be written as

$$(1-\gamma r)[p^A R_h^A + (1-p^A)] - (1-p^A)(\gamma\pi)] \geq (1-\gamma r)p^B R^B - (1-p^B)\gamma\pi \tag{101}$$

By assumption the expected return of asset A is equal to the expected return of asset B, i.e. $p^A R_h^A + (1-p^A) = p^B R^B$ and that $p^A \geq p^B$ which implies (1-p^A) $\leq (1-p^B\ )$. Under these conditions, the above equation always holds.

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