Surety Bonds and Moral Hazard in Banking

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Abstract

We examine a policy in which owners of banks provide funds in the form of a surety bond in addition to equity capital. This policy would require banks to provide the regulator with funds that could be invested in marketable securities. Investors in the bank receive the income from the surety bond as long as the bank is in business. The capital value could be used by bank regulators to pay off the banks' liabilities in case of bank failure. After paying depositors, investors would receive the remaining funds, if any. Analytically, this instrument is a way of creating charter value but, as opposed to Keeley (1990) and Hellman, Murdock and Stiglitz (2000), restrictions on competition are not necessary to generate positive rents. We demonstrate that capital requirements alone cannot prevent the moral hazard problem arising from deposit insurance.

Keywords: Banking crises, Capital requirements, Government Intervention, Moral hazard, Surety bond

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

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and elsewhere after the financial crisis, there have been many proposals to re-examine bank regulation. In a recent empirical paper Anginera, Bertay, Cullc, Demirguc-Kunt and Mare (2021) examine the evolution in bank capital regulations and bank risk after the global financial crisis. They document the importance of defining bank regulatory capital narrowly as the quality of capital matters in reducing bank risk.

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, Cooper and Ross 2002, 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.

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), the role of market incentives in general to monitor banks (Cihak, Demirgüc-Kunt, Martínez Peria and Mohseni-Cheraghlou 2013), the combination of capital and liquidity requirements (Calomiris, Heider and Hoerova 2015, De Nicolò, Gamba and Lucchertta 2014) or the role of external auditors in banking sector supervision (Masciandaro, Peia and Romellic 2020).

Restrictions on assets held are another form of prudential regulation (see Peck and Shell, 2010). In fact, portfolio restrictions (as interest rate controls proposed in Hellman, Murdock and Stiglitz, 2000) can be seen as regulatory tools that create charter value by limiting competition. In practice it is not as easy for the regulator to determine the idiosyncratic riskiness of loans. Therefore, banking regulations that attempt to limit banking risk due to high-risk loans, may not be 100 percent effective without limiting banks' investments to risk free assets. The objective of our paper is to see whether it is possible to create charter value in banking (and in this way limit moral hazard problems) without having to limit competition.

There also have been proposals for different forms of capital, not just a higher level. For example, Acharya, Mehran and Thakor (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. 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 can solve the moral hazard problem that arises because of deposit insurance.[3] We also demonstrate that capital requirements alone cannot prevent this moral hazard problem in our model.

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. Deposit insurance is then 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.

The surety bond is similar in some respects to the proposal by Acharya, Mehran and Thakor (2016) and different in others. 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

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[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.

[3]Alternatively, we could impose a portfolio restriction that requires the bank to put in the low-risk asset the amount to be set in the surety. In our model, both approaches yield the same results. We thank one of the reviewers for pointing out this possibility.

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.

It is an open question what investments would be best for the surety bond. There is no doubt that the investments should in fact be held to make payment credible and to generate the ongoing income from them.[4] Acharya, Mehran and Thakor (2016) assume that assets should be invested in Treasury securities, which is not obvious.[5] 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 which can be lost if the bank fails. We do not address this question in this paper because a full analysis would require adding risk averse investors and maybe risk averse banks. This would complicate the analysis substantially.

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. 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 deposit insurance to prevent runs and shows that deposit insurance introduces a moral hazard problem. Section five analyzes capital requirements in the presence of deposit insurance while

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[4]While the government could spend the funds received for the surety bond and create synthetic assets, this raises questions about the credibility of the promised payments.

[5]It might seem that such an investment makes the banks similar to narrow banking, but the similarity is superficial. Narrow banks hold nothing but short-term securities. Banks in our model hold whatever assets are optimal and the surety bond is a device to create charter value.

section six 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 invest it on their own. 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 $\pi > 0$.[6] 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

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

There are three types of assets available to the bank in this economy. First, there is a storage technology, which transforms one unit at $t = T$ into one unit at $T + 1$. Second, there is a 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.

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

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[6]We use the same utility function as in Chen and Hasan (2006, 2008) and Hasman, López and Samartín (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.

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

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

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 technology receives one unit of the good for consumption. As a result the impatient consumer using the 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 in storage and in one 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
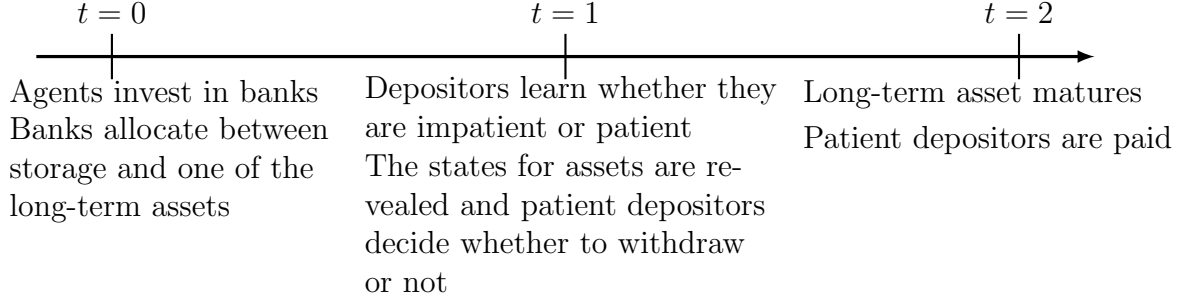
$t = 0$ — Agents invest in banks. Banks allocate between storage and one of the long-term assets

$t = 1$ — Depositors learn whether they are impatient or patient. The states for assets are revealed and patient depositors decide whether to withdraw or not

$t = 2$ — Long-term asset matures. Patient depositors are paid

Figure 1: Sequence of events

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.

Suppose that all consumers deposit their endowments in banks. Banks invest $f = \gamma c_1$ in storage and $1 - f$ in asset A.[7]

The optimal contract implies setting $c1 = r$. 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 $t = 1$.

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:

$$\frac{r + \pi}{r} > R_h^A \tag{10}$$

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.[8]

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[7] Note that in the case of asset A this strategy would be identical to investing everything in asset A, and liquidating f at date 1. We maintain storage as it is easier in terms of comparison with technology B, that is illiquid, and avoid a signaling problem.

[8] The Appendix provides the demonstration.

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 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

$$c_{2\ell}^A = \left(\frac{1 - \gamma c_1}{1 - \gamma}\right) R_\ell^A. \tag{11}$$

If $c_1 > 1$ and $R_\ell^A = 1$, then $c_{2\ell}^A < c_1$.[9]

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 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.[10]

As shown in Appendix A, the optimal contract implies setting $c_1 = r$. 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 $f = \gamma c_1$ in storage and $1 - f$ 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:*[11]

$$\mathrm{E}\, U^A = p^A[\gamma r + (1 - \gamma)c_{2h}^A] + (1 - p^A)[1 - \gamma \pi] \tag{12}$$

Proof: See the Appendix.

4. Deposit Insurance

In order to avoid bank runs, this section introduces a deposit insurance system, similar to those operated by governments in many countries (see Demirgüç-Kunt et al. 2014). Deposit

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[9]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.

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

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

insurance is introduced in a very stylized manner (See for example Cooper and Ross, 2002, Ratnovski, 2013, Ratnovski and Dell'Ariccia, 2019, Carletti, Marquez and Petriconi, 2020 or Martynova, Ratnovski and Vlahuc, 2020, among others). We assume that deposits are fully insured so that depositors always receive the promised deposit rate irrespective of whether their banks go bankrupt or not. We interpret deposit insurance as being provided by the government: if the bank goes bankrupt, the government intervenes and pays the promised interest rate r to the depositors. The cost of the deposit insurance is paid from revenues raised by non distortionary lump sum taxes.

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.[12]

This result is summarized in the following proposition:

Proposition 2. *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 $E U^{Ai}$ which equals

$$E U^{Ai} = p^A[\gamma r + (1-\gamma)c_{2h}^{Ai}] + (1-p^A)r \tag{13}$$

and

$$c_{2h}^{Ai} = \frac{(1-\gamma r)R_h^A}{(1-\gamma)}. \tag{14}$$

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

$$E U^{Bi} = p^B[\gamma r + (1-\gamma)c_{2h}^{Bi}] + (1-p^B)r \tag{15}$$

where

$$c_{2h}^{Bi} = \frac{(1-\gamma r)R^B}{(1-\gamma)} \tag{16}$$

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, $E U^{Ai} \leq E U^{Bi}$ which is

$$p^A[\gamma r + (1-\gamma)c_{2h}^{Ai}] + (1-p^A)r \leq p^B[\gamma r + (1-\gamma)c_{2h}^{Bi}] + (1-p^B)r \tag{17}$$

This equation can be rewritten

$$(p^A - p^B)\gamma r + p^A[(1-\gamma)c_{2h}^{Ai}] \leq (p^A - p^B)r + p^B[(1-\gamma)c_{2h}^{Bi}] \tag{18}$$

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[12]Allen, Carletti and Marquez, (2015) show that the moral hazard results continue to hold if the deposit insurance is priced such that it is actuarially fair from an ex-post perspective.

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

$$(p^A - p^B)\gamma r \le (p^A - p^B)r. \tag{19}$$

The remaining term is

$$p^A[(1 - \gamma)c_{2h}^{Ai}] \le p^B[(1 - \gamma)c_{2h}^{Bi}] \tag{20}$$

Making use of equations (14) and (16), equation (20) can be written as

$$p^A[(1 - \gamma r)R_h^A] \le p^B[(1 - \gamma r)R^B] \tag{21}$$

As $(1 - \gamma r) > 0$ the above condition simplifies to

$$p^A R_h^A \le p^B R^B \tag{22}$$

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

5. 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.

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

$$U_k = c_1 + c_2 \tag{23}$$

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

$$\rho \ge \mathrm{E}\, R^A. \tag{24}$$

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^{AH}), when the bank invests in asset A, is such that the expected dividend at $t = 2$ equals their opportunity cost, that is

$$p^A d_2^{AH} = \rho k \tag{25}$$

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 $1 + \bar{k} - \gamma r$.

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

$$c_{2h}^{Ak} = \frac{(1 + \bar{k} - \gamma r)R_h^A - d_2^{AH}}{(1 - \gamma)} \tag{26}$$

which can also be expressed as a function of c_{2h}^{Ai}, given by (14):

$$c_{2h}^{Aki} = c_{2h}^{Ai} + \frac{\bar{k}R_h^A - d_2^{AH}}{(1-\gamma)}. \tag{27}$$

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

$$c_{2h}^{Bki} = \frac{(1 + \bar{k} - \gamma r)R^B - d_2^B}{(1-\gamma)} \tag{28}$$

and d_2^B is the dividend paid in the high state with asset B.

Expressed as a function of c_{2h}^{Bi} from (16), this is

$$c_{2h}^{Bki} = c_{2h}^{Bi} + \frac{\bar{k}R^B - d_2^B}{(1-\gamma)} \tag{29}$$

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

Proposition 3. *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

$$p^A[\gamma r + (1-\gamma)c_{2h}^{Aki}] + (1-p^A)r \geq p^B[\gamma r + (1-\gamma)c_{2h}^{Bki}] + (1-p^B)r \tag{30}$$

Substituting the values given by (27) and (29) yields

$$p^A[\gamma r + (1-\gamma)c_{2h}^{Ai}] + (1-p^A)r + p^A\bar{k}R_h^A - k\rho \geq p^B[\gamma r + (1-\gamma)c_{2h}^{Bi}] + (1-p^B)r + p^B\bar{k}R^B - k\rho \tag{31}$$

This condition can be rewritten

$$(p^A - p^B)\gamma r + p^A(1-\gamma)c_{2h}^{Ai} + p^A\bar{k}R_h^A \geq (p^A - p^B)r + p^B(1-\gamma)c_{2h}^{Bi} + p^B\bar{k}R^B \tag{32}$$

This condition is never satisfied. First, as shown in the previous section, equation (18) always holds, i.e.,

$$(p^A - p^B)\gamma r + p^A(1-\gamma)c_{2h}^{Ai} \leq (p^A - p^B)r + p^B(1-\gamma)c_{2h}^{Bi} \tag{33}$$

Then, for the Equation (32) to hold, it is necessary that

$$p^A R_h^A \geq p^B R^B \tag{34}$$

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

6. 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. In our analysis, we assume that the regulator invests the surety in asset A, and so the surety pays R_h^A, in the high state and one unit in the low one.[13] In this case, the investment in the long-term asset equals total assets $1 + k$ less the investment in the short-term asset to satisfy impatient depositors (γr).

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

$$\max(s + 1 + k - r, 0) \tag{35}$$

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

$$\mathrm{E}\, U^{As} = p^A[\gamma r + (1 - \gamma)c_{2h}^{As}] + (1 - p^A)r \tag{36}$$

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

$$c_{2h}^{As} = \left(\frac{(1 + k - \gamma r)R_h^A - d_2^{AHs}}{1 - \gamma} \right) \tag{37}$$

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

$$p^A(d_2^{AHs} + sR_h^A) + (1 - p^A)\max\{s - [r - (1 + k)], 0\} \geq \rho(k + s) \tag{38}$$

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

$$\mathrm{E}\, U^{Bs} = p^B[\gamma r + (1 - \gamma)c_{2h}^{Bs}] + (1 - p^B)r \tag{39}$$

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

$$c_{2h}^{Bs} = \left(\frac{(1 + k - \gamma r)R^B - d_2^{Bs}}{1 - \gamma} \right) \tag{40}$$

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[13]In the numerical example, we consider the implications of investing the surety bond in other alternative investments.

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

$$p^B(d_2^B + sR_h^A) \geq \rho(k+s) \tag{41}$$

Requiring investors to post a surety bond s and capital k can prevent moral hazard at banks due to deposit insurance.[14]

This result is summarized in the following proposition:

Proposition 4. *For a given level of capital k, a policy of requiring banks to post an amount $s \geq \tilde{s}$ in a surety bond can prevent the moral hazard problem generated by deposit insurance. The level $\tilde{s}$ is given by*

$$\tilde{s} = \begin{cases} s^\star & \text{If} \quad s \leq r - (1+k) \\ s^{\star\star} & \text{If} \quad s > r - (1+k) \end{cases} \tag{42}$$

where

$$s^\star = \frac{(1+k-\gamma r)(p^B R^B - p^A R_h^A) + (p^B - p^A)\gamma r + (p^A - p^B)r}{(p^A - p^B)R_h^A}$$
$$s^{\star\star} = \frac{\gamma r[(p^B - p^A) - (p^B R^B - p^A R_h^A)] + r(1 - p^B)}{(p^A - p^B)R_h^A + (1 - p^A)} \tag{43}$$

Proof: We solve the problem for $s^\star$. The solution for $s^{\star\star}$ is derived in Appendix B.

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

$$p^A[\gamma r + (1-\gamma)c_{2h}^{As}] + (1-p^A)r \geq p^B[\gamma r + (1-\gamma)c_{2h}^{Bs}] + (1-p^B)r. \tag{44}$$

Making use of equations (84) and (86), the above condition can be rewritten:

$$p^A[\gamma r+(1+k-\gamma r)R_h^A+sR_h^A-\rho(k+s)/p^A]-p^A r \geq p^B[\gamma r+(1+k-\gamma r)R^B+sR_h^A-\rho(k+s)/p^B]-p^B r. \tag{45}$$

This can be written as

$$(p^A - p^B)[r(\gamma - 1) + sR_h^A] \geq (1 + k - \gamma r)(p^B R^B - p^A R_h^A) \tag{46}$$

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[14]Note that the surety bond is not the same as a portfolio restriction. The surety bond is required to the bank and is invested by the regulator in asset A. However, the shareholder just receives the payment from the surety bond as long as the bank is solvent. This implies that the shareholder receives different payoffs depending on the investment choice: when the bank invests in the high-risk asset (asset B), the surety is paid with probability p_B, and if the bank invests in the low-risk asset (asset A), the surety is paid with probability p_A. On the other hand, a portfolio restriction implies that the bank always receives the amount sR_h^A, with probability p_A, independently of whether it invests the rest of resources in asset A or B. This implies that while a portfolio restriction generates the same charter value whatever the investment choice of the bank, the surety bond will create more charter value when the bank invests in asset A than when it invests in asset B. In Appendix C we demonstrate how a portfolio restriction would differ from the surety bond.

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

$$s \geq s^\star = \frac{(1 + k - \gamma r)(p^B R^B - p^A R_h^A) + (p^B - p^A)\gamma r + (p^A - p^B)r}{(p^A - p^B)R_h^A} \tag{47}$$

Q.E.D

As before, incentive compatibility requires that[15]

$$c_1 \leq c_{2h}^{AS} \tag{48}$$

The basic intuition for this result is that without the surety bond capital requirements are ineffective at solving moral hazard due to limited liability. The surety bond serves to introduce the charter value effect.

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

$$p^A[\gamma r + (1 - \gamma)c_{2h}^{As}] + (1 - p^A)r \geq p^A[\gamma r + (1 - \gamma)c_{2h}^A] + (1 - p^A)[\gamma(1 - \pi) + (1 - \gamma)] \tag{49}$$

Substituting the value of c_{2h}^{As} given by equation (84) and c_{2h}^A given by (9), we have:

$$p^A[\gamma r + (1 + k - \gamma r)R_h^A + sR_h^A - \rho(k + s)/p^A] + (1 - p^A)r \geq p^A[\gamma r + (1 - \gamma r)R_h^A] + (1 - p^A)(1 - \gamma\pi) \tag{50}$$

This can be rewritten as

$$p^A[sR_h^A + kR_h^A] + (1 - p^A)(r - 1 + \gamma\pi) \geq \rho(k + s) \tag{51}$$

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 benefits are the sum of the returns from the surety bond and capital, $sR_h^A + kR_h^A$ 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 hand 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

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

14

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:

π	R_A	p_A	R_B	p_B	r	γ	k	ρ	R_s
1.20	1.30	0.90	1.70	0.75	1.01	0.60	0.10	1.27	1.30

Table 1: Parameters

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 is $\tilde{s} = 0.34$, which represents 24 per cent of total assets.[16] This result is consistent with empirical evidence (for example, Begenau (2020) shows that US capital requirements are sub-optimally low. Further, Admati and Hellwig (2013) suggest 25 per cent level of capital).

Table 2 shows how $\tilde{s}$ 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 in 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. The return of the surety is inversely related to $\tilde{s}$. Finally, the effect of the level of capital on $\tilde{s}$ can be positive or zero. Capital requirements have two opposite effects. The first one is the classical moral hazard effect due to limited liability as capital increases the returns provided in the good state (since the returns the bad state are only used to pay depositors). The second effect (which is introduced with the surety) is to reduce risk due to the skin in the game effect (charter value effect). For low levels of capital, the first effect dominates the second one and consequently, increasing capital will also increase the amount that needs to be placed in the surety. For high levels of capital, the second effect dominates. Consequently, $\tilde{s}$ is independent of the level of capital and depends only on the other parameters of the model,

To conclude this section we analyze the case where the amount put in the surety bond is less than $\tilde{s}$. 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.

$$p^B[\gamma r + (1 - \gamma)c_{2h}^{Bs}] + (1 - p^B)r \geq p^A[\gamma r + (1 - \gamma)c_{2h}^A] + (1 - p^A)[\gamma(1 - \pi) + (1 - \gamma)] \quad (52)$$

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[16]If the surety was invested in a risk-free asset, the amount to be put in the surety would increase to 28 per cent of total assets.

Parameters	$\tilde{s}$
1. $p_B R_B$	$+$
2. $p_A R_A$	$-$
3. R^S	$-$
4. γ	$-$
5. k	$+, 0$

Table 2: Comparative Statics

Substituting the value of c_{2h}^{Bs} given by equation (86) and c_{2h}^A given by (9), we have:

$$p^B[\gamma r + (1+k-\gamma r)R^B + sR^B - \rho(k+s)/p^B] + (1-p^B)r \geq p^A[\gamma r + (1-\gamma r)R_h^A] + (1-p^A)(1-\gamma\pi) \tag{53}$$

Making use of equation (6):

$$p^B[(\gamma r + k)R^B + sR^B] + (1 - p^B)r - \rho(k + s) \geq p^A \gamma r + (1 - p^A)\gamma(r - \pi) \tag{54}$$

or,

$$p^B R^B(k + s) + (1 - p^B)(1 - \gamma)r - \rho(k + s) \geq (1 - p^A)\gamma(-\pi) \tag{55}$$

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

7. Conclusion

We present a model where banks are subject to runs. Deposit insurance is then 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 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 those 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 the return 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.

From a certain point of view, our proposal has characteristics of the Prompt Corrective Action built into the FDIC Improvement Act of 1991. The bank would be closed while it still had positive assets; the difference would be that the surety bond is off balance sheet and not held by the bank. It could be a surety bond issued by a private firm, or perhaps

better, be represented by assets held directly by the regulator.[17] The rules for closing banks could be structured to make delay closing a failed bank less likely than if the assets were on balance sheet.[18]

Overall, higher levels of capital are needed, compared with the levels of capital required in an economy free of deposit insurance. This is consistent with empirical evidence (for example, Begenau (2020) shows that US capital requirements are sub-optimally low. Further, Admati and Hellwig (2013) suggest 25 per cent). This is a friction that results from deposit insurance.

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. Should investors be required to add funds 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 since additions would be needed to continue being efficient over time.

Appendix A

We will first prove that the return maximizing bank contract $\left(0, \frac{\mathrm{E}\,R^A}{1-\gamma}\right)$ dominates autarky $\left(1, \mathrm{E}\,R^A\right)$, using asset A. Second, we will determine the conditions for the income-smoothing contract $\left(r, \mathrm{E}\,c_2^A\right)$ to dominate the return-maximizing contract. Finally, we will show that with the income-smoothing contract, the expected utility of investing in asset A is at least as high as that of investing in asset B.

We start by comparing the return maximizing contract to autarky using asset A. We compare the high return state and then the low-return state, separately.

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.[19] 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 $t = 2$.

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[17]As a referee noted, private issuance of surety bonds could be subject to moral hazard.

[18]The general issue is time consistency of the policy (Chari and Kehoe 2016).

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

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

$$\mathrm{E}\left[U(1)|h\right] = \gamma(1 - \pi) + (1 - \gamma)R_h^A. \tag{56}$$

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

$$\mathrm{E}\left[U(2)|h\right] = \gamma(0 - \pi) + (1 - \gamma)\frac{R_h^A}{1 - \gamma} = R_h^A - \gamma\pi. \tag{57}$$

$\mathrm{E}\left[U(2)|h\right]$ 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

$$R_h^A - \gamma\pi \geq \gamma(1 - \pi) + (1 - \gamma)R_h^A \tag{58}$$

Eliminating $\gamma\pi$ from both sides yields

$$R_h^A \geq \gamma + (1 - \gamma)R_h^A. \tag{59}$$

Solving for R_h^A yields

$$R_h^A \geq 1 \tag{60}$$

which is satisfied by assumption.

In the low state, autarky provides $(1, 1)$ and the return-maximizing contract provides $\left(0, \frac{1}{1-\gamma}\right)$ but these different payoffs yield the same expected utility. The expected utility of the payoff in autarky is

$$\mathrm{E}\left[U(1)|\ell\right] = \gamma(1 - \pi) + (1 - \gamma) = 1 - \gamma\pi. \tag{61}$$

The expected utility of the return-maximizing contract is

$$\mathrm{E}\left[U(2)|\ell\right] = \gamma(0 - \pi) + (1 - \gamma)\frac{1}{1 - \gamma} = 1 - \gamma\pi. \tag{62}$$

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-smoothing 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

$$c_{2h}^A = \left(\frac{1 - \gamma r}{1 - \gamma}\right) R_h^A \tag{63}$$

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

$$\mathrm{E}\left[U(3)|h\right] = \gamma r + (1 - \gamma)\left(\frac{1 - \gamma r}{1 - \gamma}\right) R_h^A = \gamma r + (1 - \gamma r) R_h^A \tag{64}$$

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

$$\gamma r + (1 - \gamma r) R_h^A \geq R_h^A - \gamma \pi. \tag{65}$$

This is equivalent to

$$\pi > r(R_h^A - 1) \tag{66}$$

or

$$\frac{r + \pi}{r} > R_h^A \tag{67}$$

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 (10).

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

$$c_{2h}^A \geq c_1 = r \tag{68}$$

and this inequality can be written

$$R_h^A \geq \frac{r(1 - \gamma)}{(1 - \gamma r)} \tag{69}$$

Finally, we need to prove that $EU^A \geq EU^B$ given the bank contract. The expected utility from investing in the income-smoothing bank contract is

$$EU(3) = p^A \left[\gamma r + (1 - \gamma r) R_h^A\right] + \left(1 - p^A\right) [1 - \gamma \pi]. \tag{70}$$

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

$$c_{2h}^B = \left(\frac{1 - \gamma r}{1 - \gamma}\right) R^B. \tag{71}$$

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

$$E[U(4)|\ell] = \gamma (r\gamma - \pi) + (1 - \gamma)(r\gamma) = \gamma (r - \pi) \tag{72}$$

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

$$EU(4) = p^B \left[\gamma r + (1 - \gamma r) R^B\right] + \left(1 - p^B\right) [\gamma (r - \pi)] \tag{73}$$

$EU(3) \geq EU(4)$ if

$$
\begin{array}{c}
p^A \left[\gamma r + (1 - \gamma r) R_h^A\right] + \left(1 - p^A\right) [1 - \gamma \pi] \\
\geq \\
p^B \left[\gamma r + (1 - \gamma r) R^B\right] + \left(1 - p^B\right) [\gamma (r - \pi)]
\end{array}
\tag{74}
$$

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

$$\gamma r + p^A(1 - \gamma r)R_h^A + (1 - p^A)[(1 - \gamma r - \gamma\pi)] \geq \gamma r + p^B[(1 - \gamma r)R^B] + (1 - p^B)\gamma[-\pi]. \tag{75}$$

Canceling γr on both sides yields

$$p^A(1 - \gamma r)R_h^A + (1 - p^A)[(1 - \gamma r - \gamma\pi)] \geq p^B[(1 - \gamma r)R^B] + (1 - p^B)\gamma[-\pi] \tag{76}$$

which can be written as

$$(1 - \gamma r)[p^A R_h^A + (1 - p^A)] - (1 - p^A)(\gamma\pi)] \geq (1 - \gamma r)p^B R^B - (1 - p^B)\gamma\pi \tag{77}$$

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.

8. Appendix B

We now consider the case where $s > r - (1 + k)$.

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

$$p^A[\gamma r + (1 - \gamma)c_{2h}^{As}] + (1 - p^A)r \geq p^B[\gamma r + (1 - \gamma)c_{2h}^{Bs}] + (1 - p^B)r. \tag{78}$$

Making use of equations (84) and (86), the above condition can be rewritten:

$$p^A[\gamma r + (1 + k - \gamma r)R_h^A + sR_h^A] + (1 - p^A)(s + 1 + k - r) - p^A r \geq p^B[\gamma r + (1 + k - \gamma r)R^B + sR_h^A] - p^B r. \tag{79}$$

This can be written as

$$(p^A - p^B)[r(\gamma - 1) + sR_h^A] + (1 - p^A)s \geq (1 + k - \gamma r)(p^B R^B - p^A R_h^A) - (1 - p^A)(1 + k - r) \tag{80}$$

And solving for $s^{\star\star}$

$$s^{\star\star} = \frac{(1 + k - \gamma r)(p^B R^B - p^A R_h^A) + (p^B - p^A)\gamma r + (p^A - p^B)r - (1 - p^A)(1 + k - r)}{(p^A - p^B)R_h^A + (1 - p^A)} \tag{81}$$

or

$$s^{\star\star} = \frac{\gamma r[(p^B - p^A) - (p^B R^B - p^A R_h^A)] + r(1 - p^B)}{(p^A - p^B)R_h^A + (1 - p^A)} \tag{82}$$

Q.E.D

Appendix C

In the context of our model a portfolio restriction is not the same as a surety bond. We will try to show whether a portfolio restriction for an amount s can solve the moral hazard problem. For that purpose, we compare expected utilities when investing in both assets, along the same lines as it was carried out in the surety bond section.

$$p^A[\gamma r + (1 - \gamma)c_{2h}^{PR}] + (1 - p^A)r \geq p^B[\gamma r + (1 - \gamma)c_{2h}^{PR}] + (1 - p^B)r \tag{83}$$

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

$$c_{2h}^{PR} = \left(\frac{(1 + k + s - \gamma r)R_h^A - d_2^{AHp}}{1 - \gamma}\right) \tag{84}$$

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

$$p^A d_2^{AHp} + (1 - p^A)\max\{s - [r - (1 + k)], 0\} \geq \rho(k + s) \tag{85}$$

Similarly, consumption in the second period in the high state when the bank invests in asset

B is given by

$$c_{2h}^{PR} = \left(\frac{(1 + k - \gamma r)p^B R^B + sp^A R_h^A - p^B d_2^{Bp}}{1 - \gamma} \right) \tag{86}$$

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

$$p^B d_2^{Bp} \geq \rho(k + s) \tag{87}$$

IF we substitute second period consumption in both cases and operate we obtain

$$p^A[\gamma r + (1 + k - \gamma r)R_h^A] + p^A s R_h^A - p^A r + (1 - p^A)\max\{s - [r - (1 + k)], 0\} \geq$$
$$p^B[\gamma r + (1 + k - \gamma r)R^B] + p^A s R_h^A - p^B r \tag{88}$$

When $\max\{s - [r - (1+k)], 0\} = 0$, we observe there is no level of s that solves the moral hazard problem in the presence of portfolio restrictions (they cancel out from both sides of the inequality) while it exists for the case of the surety bond, $s^\star$, given in equation (43). Note that in this case the portfolio restriction generates the same charter value no matter the investment choice of the bank.

If $\max\{s - [r - (1 + k)], 0\} > 0$, we could find a level of s. In this case, the portfolio restriction generates higher charter value when the bank invests in asset A. However, the amount required is higher in comparison to the surety bond.

In fact, the level of s would be given by

$$s^{PR} = \frac{\gamma r[(p^B - p^A) - (p^B R^B - p^A R_h^A)] + r(1 - p^B)}{(1 - p^A)} \tag{89}$$

which is higher than $s^{\star\star}$ given in equation (43).

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