Finnish Economic Papers – Volume 16 – Number 1 – Spring 2003

FAIRLY PRICED DEPOSIT INSURANCE UNDER ADVERSE SELECTION*

JUHA-PEKKA NIINIMÄKI

School of Business and Economics, P.O. Box 35, FIN-40014 University of Jyväskylä, Finland

Fair pricing of deposit insurance represents one of the most difficult problems of bank regulation. This paper introduces an incentive compatible mechanism such that fair (risk-based) deposit insurance premiums can be achieved under adverse selection. The deposit insurer screens banks by offering full insurance coverage for high-risk banks and partial coverage for low-risk banks. If deposit interest rates can be regulated, low-risk banks also obtain full coverage. The optimal solution may require dividing deposits into junior and senior deposits. More generally, our analysis connects deposit insurance with standard insurance theory. (JEL: G21, G22, G28)

1. Introduction

The immense costs of recent bank crises – e.g., in Japan, the Nordic countries and the United States – have spawned a heated debate on deposit insurance reform. We extend this debate by studying deposit insurance in a standard insurance framework in the presence of adverse selection. Moreover, we design a novel self-selection mechanism that makes banks optimally reveal their true risks. The mechanism utilizes banking and insurance theories.

Banking literature emphasizes the negative incentive effects of deposit insurance. Using option theory, Merton (1977) demonstrates that deposit insurance encourages banks to take excessive risks.[1] While the moral hazard problem has received considerable attention, the adverse selection problem is not fully understood (despite convincing empirical evidence of adverse

* *I would like to thank the editor and two anonymous referees for their professional comments that have greatly improved the study. Financial support from the Yrjö Jahnsson Foundation is gratefully acknowledged.*

[1] *There are several recent studies on the moral hazard problem of deposit insurance. Matutes and Vives (2000) study the welfare implications of banking competition under various deposit insurance policies in a model of imperfect competition with social failure costs and where banks are subject to limited liability. John et al. (2000) demonstrate how moral hazard can be controlled through compensation to bank management. Chiesa (2001) examines how the moral hazard problem of deposit insurance can be reduced by using capital requirements. Social-welfare-maximizing capital requirements are lowered in recessions, are higher the more fragmented the banking sector, and are increased when anti-competitive measures are removed. Hyytinen and Takalo (2002) demonstrate that excessive transparency may decrease a bank's charter value, and hence worsen the moral hazard problem. Niinimäki (2001) shows how intertemporal diversification' – reinvesting the bank's loan portfolio slowly over a long period – reduces the moral hazard problem of deposit insurance. Freixas and Rochet (1997) survey the literature.*

selection).[2] Interestingly, Chan, Greenbaum and Thakor (1992) point out that fairly priced deposit insurance cannot be achieved in the presence of adverse selection using *price-equity combinations*. Their seminal analysis is extended by Freixas and Rochet (1998), who show that under more general assumptions about a bank's operating costs, fairly priced deposit insurance, although not optimal, can be achieved. Nagarajan and Sealey (1998) achieve fairly priced deposit insurance in the presence of adverse selection when the regulator can decompose bank asset risk into market and unique components, and implement an'*ex post* pricing contingent on the state of the market. This paper contributes to the analysis on adverse selection. While the earlier works use price-equity combinations in screening, this paper uses *price-coverage* combinations.

Standard insurance theory comprises the second body of related literature. In Rothschild and Stiglitz (1976), the insurer screens agents utilizing price-coverage combinations so high-risk agents receive full insurance coverage and low-risk agents receive partial coverage. Their classic article has been extended in many later papers; e.g., Stiglitz (1977) investigates monopoly, Crocker and Snow (1986) focus on categorization, whereas Cooper and Hayes (1987) and Dionne and Doherty (1994) examine multi-period contracts. This paper extends the Rothschild and Stiglitz model to deposit insurance. The bank purchases insurance and pays a premium, but when an accident (bank failure) occurs, the insurer does not pay an indemnity to the bank or to the bank's stockholders – it pays an indemnity to the depositors. The bank gains from insurance through the low deposit rate when failure does not occur. The optimal deposit insurance scheme proves to be similar to the original model; a high-risk bank receives full coverage, while a low-risk bank receives partial coverage. Interestingly, this separating equilibrium can be improved by regulating deposit rates so that a low-risk bank receives (near) full coverage. The optimal solution may require dividing deposits into junior and senior deposits.

This paper has two main contributions. We first highlight the demand for deposit insurance, asking what motivates a bank to purchase insurance to protect its depositors. This is important in cases where the regulator will not insure all types of deposits or if deposit insurance is voluntary. The second issue is the applicability of standard insurance theory to deposit insurance. If a valid connection exists, it is possible to use the numerous findings of standard insurance theory to enrich the analysis of deposit insurance.

Although this paper resembles Chan et al. (1992), there are many differences. Recall that we use price-coverage combinations in contrast to the price-equity combinations of Chan et al. That is, Chan et al. use bank equity in screening; a low-risk bank chooses a deposit insurance contract with a lower insurance premium and a larger equity requirement than a high-risk bank.[3] Intuitively, since an insolvent bank loses its equity, the risky equity investment is more costly for a high-risk bank. In our model, the banks have no equity. Moreover, in Chan et al. (1992) all deposits are fully insured, whereas our model uses partial insurance coverage in screening; a low-risk bank chooses a deposit insurance contract with a lower insurance premium and smaller coverage than a high-risk bank. Intuitively, since a high-risk bank must pay a higher risk premium for partially insured deposits, partial coverage is more costly for the high-risk bank. The two screening methods have different information needs. In Chan et al. (1992), the banker needs to know bank risk, but depositors can be uninformed. In our model,

[2] *For empirical evidence on adverse selection see, e.g., Calomiris (1989), Wheelock and Kumbhakar (1995) or Gunther et al. (2000). Studying historical deposit insurance schemes during the 1900s, Calomiris (1989) finds that banks tended to join schemes after their financial prospects had already deteriorated, while solvent banks withdrew from such schemes. Wheelock and Kumbhakar examine voluntary deposit insurance schemes in Kansas from 1909 to 1929. They find that the lower a bank's capital/asset or surplus/loans ratio, the more likely it was to be a member of the insurance scheme later. New banks also joined the schemes relatively often. Gunther et al. (2000) find that new and small banks with lower capital ratios joined deposit insurance schemes in pre-depression Texas.*

[3] *In Chan et al. (1992), the insurer can screen banks only under subsidized deposit insurance.*

both the banker and some depositors need to recognize bank risk – the depositors can then price partially insured deposits correctly. Our model is thus more restricted than Chan et al. (1992). Fortunately, empirical evidence strongly supports our assumption that depositors can recognize bank risk: e.g., Flannery (1998), Jordan (2000), Jordan et al. (2000) and Sironi (2000). Besides, due to the high costs of bank equity (e.g., Calomiris and Wilson, 1998) the price-coverage screening method may be preferable to the price-equity method. The models also differ in other, less important, contexts. For example, we assume a monopoly bank, whereas Chan et al. (1992) parametrize the division of investment surplus.

Finally, we will review existing deposit insurance schemes. Garcia (1998) surveys 50 existing deposit insurance schemes and finds that:

- To avoid the problems of adverse selection, 41 of the schemes were compulsory.
- Only 8 schemes covered deposits of all types and 14 covered most deposits. 12 schemes excluded foreign currency deposits, 36 did not cover interbank deposits, and 8 guaranteed only household deposits.
- 43 schemes limited insurance coverage.
- 38 schemes maintained a deposit insurance fund, whereas 9 imposed ex post payments on surviving banks when failure occurred.
- The administration varied from country to country; 11 of the schemes were privately administered, the government run 23 of the schemes, and 14 were jointly operated.

Although Garcia favors risk-based insurance premiums, bank regulators have mostly adopted risk-based equity standards (e.g., Basle accords).[4] As far as we know, the price-coverage method has not been adopted. This method may have a few shortcomings. First, partial coverage may make low-risks banks subject to bank runs. Second, the price-coverage method is based on market discipline, which requires some informed depositors. Third, given the need for market discipline, the method operates effectively only if an insolvent bank is closed down and if the closure causes losses to partially insured depositors. In practice, regulators usually pay financial assistance to an insolvent bank in order to prevent a closure, thereby making all deposits risk-free and removing market discipline (see Freixas and Rochet, 1997, pp. 279–281).

2. The model

Consider an economy with numerous risk-averse depositors, a bank and a risk-neutral deposit insurer. The bank size is fixed at 1, it has no equity, it grants standard loans and finances its lending by attracting deposits.[5] The bank is either low-risk (L) or high-risk (H), and its risk type is observable but non-verifiable. Thus, the deposit insurer cannot enforce risk-based insurance payments even if depositors can utilize the risk information in their saving decisions. This assumption is discussed in detail in Section 5.

A low-risk (high-risk) bank earns loan interest R_L (R_H) with probability p_L (p_H, $p_L > p_H$), whereas with probability $1 - p_L$ ($1 - p_H$) the loans produce no returns and the bank fails. Besides, a low-risk (high-risk) bank pays interest r_L (r_H) on deposits. Hence, the bank earns expected profits $p_i (R_i - r_i)$, $i \in \{L, H\}$. Risk-averse depositors possess utility functions u (), which are strictly increasing and strictly concave. Given the bank risk, an uninsured bank deposit provides an expected utility

$$(1) \qquad \hat{V}(p_i;r) = p_i u(r_i) + (1 - p_i) u(0),$$

to a depositor. That is, with probability p_i, the bank succeeds and pays interest r_i on deposits, whereas with probability $1 - p_i$ the bank fails and depositors receive no returns. Alternatively, a depositor can save in a risk-free asset, e.g., a government bond, which pays interest r_f. A depositor will save in a bank if the expected utility of a bank deposit is at least the same as the utility of the risk-free saving alternative, $\hat{V}(p_i; r) \geq u(r_f)$. The deposit rate thus exceeds the risk-free interest rate, $r_i > r_f \geq 1$.

[4] *For risk-based equity capital standards, see Dewatripoint and Tirole (1993, 47–63). For existing deposit insurance schemes, see also Garcia (1999).*

[5] *For the optimality of the standard loan contracts see Diamond (1984), Aghion and Bolton (1992) and Vauhkonen (2002).*

Next, we will extend the model with deposit insurance. The deposit insurer, an agent of the government, is risk-neutral and earns zero expected profits. The deposit insurer wants to price insurance fairly (according to true failure probabilities), so there are *two zero-profit constraints for the insurer*. The *insurance premium* of the low-risk insurance policy is

(2) $P_r^L = 1 - p_L$.

Under the low-risk deposit insurance policy, a depositor receives an indemnity x_L in the event of the bank failure. The bank pays an *insurance payment* $x_L P_r^L$ at the beginning of the period. Hence, the payment depends both on the premium P_r^L and chosen indemnity x_L. The zero-profit condition for a high-risk insurance policy is

(3) $P_r^H = 1 - p_H$.

Correspondingly, the indemnity is x_H and the insurance payment is $x_H P_r^H$. Over-insurance is not allowed, $x_L, x_H \leq r_f$. Under deposit insurance, a depositor will save in a bank if,

(4) $V(p_i; r_i; x_j) = p_i u(r_i) + (1 - p_i) u(x_j) \geq u(r_f), \quad i, j \in \{L, H\}$

That is, the expected utility of a bank deposit is at least the same as the utility of the risk-free saving alternative. With probability p_i, the bank succeeds and pays interest r_i on deposits, whereas with probability $1 - p_i$ the bank fails and a depositor receives the indemnity, x_j. The insurer must select the indemnities (x_L, x_H) so that the risk types can be screened; a low-risk bank chooses a low-risk deposit insurance policy (P_r^L, x_L) and a high-risk bank chooses a high-risk policy (P_r^H, x_H). To sum up, the time line is the following.

1. A bank is formed. Its risk p_i, $i \in \{L, H\}$, is observable but non-verifiable.
2. The insurer supplies two deposit insurance policies, (P_r^L, x_L) and (P_r^H, x_H).
3. The bank chooses the insurance policy maximizing its profit and announces the policy, as well as its rates to depositors and borrowers.
4. The bank pays the insurance payment from the retained returns of the previous period.
5. Depositors either accept or reject the bank's offer. The offer is accepted if the expected utility of the bank deposit is at least the same as the utility from the risk-free saving alternative.
6. After collecting the deposits, the bank grants loans.
7. Loan returns materialize. If the loans succeed, the bank repays the deposits and the banker receivers the rest of the returns. If the loans fail, the bank is insolvent, the insurer indemnifies the deposits, and the banker receives no returns.

Next, we will design the bank's profit maximization problem in detail. To begin, there exist *four participation constraints for depositors.* The bank has market power in the deposit market and it can attract an infinite amount of deposits by providing the reservation utility $u(r_f)$ to depositors. If a low-risk bank chooses the low-risk insurance policy, it must offer deposit rate r_{LL} such that depositors' participation constraint is satisfied (in r_{ij} subscript denotes the bank's true risk type, $i \in \{L, H\}$, whereas subscript j denotes the chosen insurance policy, $j \in \{L, H\}$).

(5) $p_L u(r_{LL}) + (1 - p_L) u(x_L) \geq u(r_f)$.

If a high-risk bank buys the high-risk insurance policy, it must pay a deposit rate r_{HH} such that

(6) $p_H u(r_{HH}) + (1 - p_H) u(x_H) \geq u(r_f)$.

If a low-risk bank buys the high-risk insurance policy, its deposit rate r_{LH} satisfies

(7) $p_L u(r_{LH}) + (1 - p_L) u(x_H) \geq u(r_f)$.

If a high-risk bank chooses the policy designed for a low risk, the deposit rate r_{HL} is such that

(8) $p_H u(r_{HL}) + (1 - p_H) u(x_L) \geq u(r_f)$.

Because the risk is observable, depositors value deposits correctly; the deposit rate depends both on the bank's true risk and on the chosen indemnity. Hence a high-risk bank must pay higher interest on partially insured deposits than a low-risk bank.

The insurer designs insurance policies so that both bank types will choose the policy intended for it. There are *two self-selection constraints* *for the bank*. The expected profits of the low-risk bank are maximized if it chooses the low-risk insurance policy

(9) $p_L (R_L - r_{LL}) - x_L P_r^L \geq$
$p_L (R_L - r_{LH}) - x_H P_r^H,$

which can be simplified to

(10) $p_L r_{LH} + x_H P_r^H \geq p_L r_{LL} + x_L P_r^L.$

Second, the expected profits of the high-risk bank are larger if it chooses the high-risk policy

(11) $p_H (R_H - r_{HH}) - x_H P_r^H \geq$
$p_H (R_H - r_{HL}) - x_L P_r^L,$

which can be simplified to

(12) $p_H r_{HL} + x_L P_r^L \geq p_H r_H + x_H P_r^H.$

Expression (10) guarantees that the total cost of attracting deposits – expected payments to depositors and the insurance payment – are minimized when a low-risk bank chooses its own policy. Expression (12) does the same for a high risk. The bank (which is thus either low-risk or high-risk) maximizes the social surplus by maximizing its expected profits

(13) $p_L (R_L - r_{LL}) - x_L P_r^L +$
$p_H (R_H - r_{HH}) - x_H P_r^H.$

The expected profits of the bank (13) are maximized subject to the four participation constraints for depositors, (5)–(8), two zero profit constraints for the insurer, (2)–(3), and two self-selection constraints for the bank; (10),(12).[6] The problem can be greatly simplified by solving for all four deposits rates (r_{LL}, r_{LH}, r_{HH}, r_{HL}) from (5)–(8) using inverse utility functions and inserting the deposit rates in the objective function (13) and in the self-selection constraints (10),(12). Moreover, insurance premiums can be transferred from (2) and (3) to the objective function (13) and to the self-selection constraints (10), (12). After these simplifications, bank profit is maximized subject to the two self-selection constraints. A solution is presented in the following proposition (see proof in the appendix).

Proposition 1.

a) A high-risk bank receives full coverage and can pay risk-free interest r_f on deposits.
b) The deposits of a low-risk bank are less-than-fully insured, $x_L < r_f < r_L$.
c) A high-risk bank is indifferent between a high-risk contract and a low-risk contract.

The solution is similar to the separating equilibrium which Rothschild and Stiglitz presented in the standard insurance setting. Intuitively, under deposit insurance the bank pays the insurance, but when the risk materializes, the insurer indemnifies the realized losses of the depositors. On the surface, it appears that the bank has no reason to insure. The demand for insurance can, however, be derived from the interest claims of depositors. The bank effectively inherits the risk aversion of its depositors and so behaves as if it were a risk-averse purchaser of insurer. Hence, both bank types would like to purchase full insurance. However, if the insurer supplied only a single pooling insurance contract, a low-risk bank would subsidize a high-risk bank through insurance.[7] To avoid subsidization and achieve fairly priced deposit insurance, the insurer screens bank types by

[6] *A low-risk bank maximizes its profits subject to the insurer's break-even constraint and its depositors' participation constraint. Equally, a high-risk bank maximizes its profits subject to the insurer's break-even constraint and its depositors' participation constraints. Besides, in equilibrium both self-selection constraints need to be satisfied. Hence, the maximization problem can be solved in the simplified form when the expected profits of the two bank types are maximized subject to the insurer's and depositors' participation constraints and the two self-selection constraints. The probability that a bank is low-risk or high-risk is insignificant since both deposit insurance policies are priced fairly. In the most familiar screening models the probability matters, since the insurer is a profit maximizing monopolist (Stiglitz, 1977) or low-risk agents subsidize high-risk agents through insurance (Rothschild and Stiglitz (1976, pp. 643–645), Crocker and Snow, 1985, 1986).*

[7] *More precisely, if the insurer supplied only a pooling insurance policy with full insurance coverage, this policy might be purchased by both bank types. Alternatively, the pooling insurance premium might be so high that a low-risk bank would rather keep out of the deposit insurance scheme. A standard adverse selection problem would then appear. Only a high-risk bank would join the scheme, thereby pushing up the break-even insurance premium. A low-risk bank would rather operate without deposit insurance paying the risk premium in their deposit rate. Note that the adverse selection problem is avoided in the absence of deposit insurance, since depositors can observe bank risk.*

supplying full insurance for a high-risk bank and partial insurance for a low-risk bank. A high-risk bank values insurance more than a low-risk bank because it must pay higher interest on partially insured deposits. Hence, the high-risk bank obtains full coverage. The existence of a high-risk bank reduces the coverage of the low-risk policy. If the insurer offered greater coverage to a low-risk bank, the high-risk bank would also choose the same policy, and thus cause financial losses to the insurer.[8]

Suppose now that there are several banks identical to the original bank.[9] In the deposit markets, the banks have market power and they can push depositors down to the reservation utility level. Hence, the case is identical to the monopoly case; the banks attempt to minimize the total cost of attracting deposits (expected payments to depositors and the insurance payment). The optimal insurance solution is also identical as above. However, now the banks compete for given borrowers. Low-risk banks compete with each other for low-risk borrowers so that their loan interest rate drops to the zero-profit level. High-risk banks compete with each other for high-risk borrowers and their loan interest rate drops to a zero-profit level, Hence, competition for borrowers pushes loan interest down to each bank's zero-profit level.[10]

3. *Deposit rate regulation*

Deposit rate can be expressed by using an inverse utility function as follows

$$r_i = u^{-1}\left\{\frac{u(r_f)-(1-p_i)u(x)}{p_i}\right\}, \quad i \in \{L, H\}. \tag{14}$$

Obviously a safer bank pays lower interest on deposits

$$\frac{\partial r_i}{\partial p_i} = -\frac{u(r_f)-u(x)}{p_i^2 \; u'(r_i)} < 0 \; .$$

A high-risk bank must pay higher interest on deposits if insurance coverage is partial, $x < r_f$. The insurer can offer an almost complete in-

[8] *We have followed the Rothschild and Stiglitz equilibrium concept; equilibrium is a set of insurance policies such that, when consumers choose policies to maximize expected utility, each policy yields zero profit. There exist two main differences between the Rothschild and Stiglitz model and our model. First, in the Rothschild and Stiglitz model competition among insurers causes an equilibrium existence problem. This has raised a question concerning the definition of equilibrium (Miyazaki, 1977; Crocker, 1985). No equilibrium existence problems arise in our setting, since the insurer is a monopoly (See Section 5 for a more detailed discussion). The second difference is that standard insurance involves two parties (the insurer and the entity protected), but deposit insurer involves three parties (the insurer, the bank, the depositors). Hence, under deposit insurance the equilibrium is more complex. However, it is easy to see that the optimal solution (Proposition 1) is equilibrium. Each saving asset – a risk-free bond, a deposit of the low-risk bank, a deposit of the high-risk bank – provides the same reservation utility level to depositors. Given the excess supply of deposits, the bank has market power in the deposit markets, and the depositors cannot obtain more utility. Identically, the bank has market power in the loan market and it can raise the loan rate to the upper limit. Hence, the bank's profit is maximized; the bank cannot drop the deposit rate below the depositors' reservation level and it cannot raise the loan rate above the upper limit. Besides, each bank type chooses the deposit insurance policy that maximizes its profit. Since each bank chooses the policy intended for it, the insurer breaks even. The insurer could design insurance policies that allow him to earn positive profit. However, we have assumed that the insurer – an agent of the government – does not attempt to maximize his profit. Moreover, as an agent of the government, the insurer is a monopoly. Thus, the entry of competing insurers is avoided and no equilibrium existence problems arise.*

[9] *When several banks exist, a depositor may want to limit his risk by diversifying his savings among a number of banks. Is there, in fact, still a need for deposit insurance in this case? We make five observations. First, if bank risks are correlated, the entire risk cannot be diversified away. Historically, bank failures have tended to occur simultaneously. Second, diversification may be expensive, since deposit accounts often include fixed payments. Third, minimum deposit requirements may rule out diversification. Fourth, having access to a payment system is a major motive for demand deposits. This requires significant balances, which would rule out diversification. Fifth, a bank may be a local monopoly in deposit markets. To simplify the analysis, we deny the diversification option.*

[10] *If deposits are scarce, the banks compete for them. Two cases may occur. In the first case, both banks operate and the insurer can screen them. In the second case, deposits are very scarce and competition for them will drive the other bank type out. The winning type may be low-risk or high-risk. The banks of the winner type then compete with each other until competition drives all banks to the zero-profit level. Since only one bank type operates, screening is unnecessary. We do not here explore competition for deposits in detail, since the analysis is quite complex.*

demnity $r_f - \varepsilon$ ($\varepsilon > 0$, but very small) to a low-risk bank if he simultaneously includes a deposit rate ceiling,

$$(15) \quad \bar{r}_{LL} = u^{-1}\left\{\frac{u(r_f) - (1-p_L)u(r_f - \varepsilon)}{p_L}\right\},$$

in the low-risk insurance policy. The insurance policies now include three elements: premium, indemnity, and deposit-rate ceiling. If the insurer offers two insurance policies, $[1 - p_L, r_f - \varepsilon, \bar{r}_{LL}]$ and $[1 - p_H, r_f, r_f]$, a low-risk bank chooses the first policy, while a high-risk bank prefers the second. A high-risk bank cannot purchase the low-risk insurance policy, since it is unable to pay sufficient risk premium to depositors due to the deposit rate regulation. More precisely, a low-risk bank can attract depositors by paying interest $\bar{r}_{LL}$ on deposits, but a high-risk bank cannot. The special characteristic of deposit insurance – bank risk is priced into the deposit rate later— makes near full coverage now attainable.

Proposition 2. The insurer can improve the separating solution through deposit-rate ceilings. A high-risk bank receives full coverage, while a low-risk bank receives near full coverage.

4. Junior and senior deposits

We have so far assumed that the bank has no wealth when it fails. Let us now extend the analysis by assuming that the bank's wealth is R_B in such conditions, so that $0 < R_B < r_f$. (Since $R_B < r_f$, the bank's depositors receive all the bank's assets' R_B in a bankruptcy, whereas the bank's shareholders obtain no returns.). The deposits can now be divided in two parts; a fraction R_B / r_f of them is senior, while the rest of the deposits, $1 - R_B / r_f$, is junior. Each bank attracts both types of deposits. We further assume that only some depositors observe the risk. These informed depositors then choose junior deposits, while safe senior deposits are preferred by uninformed depositors.[11] If the proportion of uninformed depositors does not exceed R_B / r_f, all of them can save in completely safe senior deposits. Informed depositors then have all risky junior deposits and the insurer can utilize market discipline as if the bank risk was observable to all depositors. If the insurer posts a menu of deposit insurance policies, a high-risk bank chooses full coverage for its junior deposits and a low-risk bank chooses partial coverage. Senior deposits can be fully insured in both bank types. The solution can again be improved by regulating deposit rates.[12]

5. Discussion on assumptions

5.1 Non-verifiable bank risk

There are various reasons why bank risk may be observable for depositors but non-verifiable for the insurer. For example, Garcia (1999, p. 12) argues that "the risk premiums imposed by the DIA (Deposit Insurance Agency) need to be based on objective criteria so that they can be justified to the bank and courts, should the bank challenge the ruling." Moreover, Matutes and Vives (2000) argue "Note that even if the asset risk position of banks is observable it need not be verifiable for regulatory purposes. That is, well-informed investors may base their decisions on soft information but regulatory actions need to be based on hard information. This verifiability problem explains why typically it is not possible to control directly the risk of the portfolio of a bank." (Matutes and Vives, 2000, p. 16). Let us give an example. In the 1990s, regulators in many countries introduced risk-based bank equity requirements. Under the standard form of the requirement, a bank loan

[11] *The bank does not know who are informed. Instead, both depositor types willingly select the deposit contract intended for it.*

[12] *In reality, the opposite situation appears; junior deposits are not insured at all. For example, under the risk-based capital requirements (Basle accords), the risky bank capital may include long-term junior debt, which is uninsured (Dewatripont and Tirole, 1993, pp. 47–61). Besides, according to the Garcia's (1998) survey many countries have found it necessary to insure only certain types of deposits, thus ensuring that the classes of sophisticated depositors remain uninsured. In reality, there may exist only a few informed depositors with very large deposits. Hence, these depositors might have considerable bargaining power and they might be able to raise their deposit rate above the reservation utility level.*

was categorized into one of four risk classes. Unfortunately, all commercial loans were bundled under the same, most risky, class. Thus, since the regulators had to base their decisions on verifiable facts, the categorization was quite uninformative. Besides, the regulators had to focus on individual loan risks, while the portfolio risk was excluded. These shortcomings strongly reduced the value of the risk-based equity requirements.

In our model, screening is impossible if bank risk is totally unobservable. As mentioned earlier, evidence indicates that depositors can observe bank risk: e.g., Flannery (1998), Jordan (2000), Jordan et al. (2000) and Sironi (2000).

5.2 Equilibrium

We have a few remarks concerning the equilibrium. First, in Rothschild and Stiglitz (1976) competition drives the insurer's profits from each insurance policy down to zero and causes an equilibrium existence problem; only a separating equilibrium may exist. No equilibrium existence problems arise in our setting, because we have no competitive markets for deposit insurance; the insurer has a monopoly. This assumption is quite realistic, since the insurer is often an agent of the government. Mutual deposit insurance funds also exist, but as far as we know, they do not compete with each other as do standard insurance companies. Second, even if the insurer is a monopoly, he earns zero profits. Whether the insurer is an agent of the government or a mutual fund, it seems rather realistic that he does not aim to maximize his profits. We thus exclude the problem of the self-interested bank regulator/insurer (see Boot and Thakor, 1993). Third, the insurer earns zero profits from each insurance policy. This assumption is the most problematic. In the Rothschild and Stiglitz setting, the expected utility of both risk types may be increased by cross-subsidization (Rothschild and Stiglitz, 1976, pp. 643-644; Miyazaki, 1977; Crocker and Snow, 1985, 1986). Intuitively, it is possible that low-risk agents will subsidize a high-risk insurance policy. The subsidy makes the high-risk policy more lucrative and the high-risk agents will choose their own policy even if the insurer enlarges the coverage of the low-risk policy a little. Hence, by subsidizing the high-risk policy, the low-risk agents may enlarge the coverage of the low-risk policy. This improvement option is thus forbidden in our model by forcing zero profits from each insurance policy. However, in our model the separating equilibrium can be improved at lower cost by setting ceilings on deposit rates. With subsidies, low-risk banks can receive little more coverage at the extra cost of the subsidy. With ceilings, low-risk banks can receive nearly full coverage without extra costs. Thus, the low-risk banks prefer the separating equilibrium with ceilings to the separating equilibrium with subsidies. Most of all, we have wanted to focus on the fairly priced insurance policies, since the emphasis in deposit insurance literature is on such policies, e.g., Chan et al. (1992), Freixas and Rochet (1998) and Nagarajan and Sealey (1998).

6. Conclusions

This paper extends the analysis of optimal deposit insurance schemes by connecting the analysis of deposit insurance with standard insurance theory (Rothschild and Stiglitz, 1976). Moreover, it presents a novel self-selection mechanism so that fair-priced deposit insurance can be achieved in the presence of adverse selection. The insurer can screen banks by issuing full insurance coverage for high-risk banks and partial coverage for low-risk banks. High-risk banks value deposit insurance more than low-risk banks because they must pay higher interest on partially insured deposits. Hence, high-risk banks are ready to reveal their true risk and pay high deposit insurance premium to be able to receive full coverage for their deposits.

Appendix

We maximize the expected profits of the bank (13) subject to the eight constraints (2), (3), (5)–(8), (10), (12). Because the competition for deposits is such that depositors receive their reservation utility and the insurer earns zero profits, the social value of the insurance is maximized when we maximize the expected profits of the bank. Each bank type offers interest such that depositors' participation constraints (5)–(8) are binding. The four deposit rates can thus be solved using inverse utility functions

$$\text{(A.1)}\quad r_{LL} = u^{-1}\left\{\frac{u(r_f) - (1-p_L)u(x_L)}{p_L}\right\},$$

$$r_{HH} = u^{-1}\left\{\frac{u(r_f) - (1-p_H)u(x_H)}{p_H}\right\},$$

$$r_{LH} = u^{-1}\left\{\frac{u(r_f) - (1-p_L)u(x_H)}{p_L}\right\},$$

$$r_{HL} = u^{-1}\left\{\frac{u(r_f) - (1-p_H)u(x_L)}{p_H}\right\}.$$

By inserting the insurance premiums, $P_r^L = 1 - p_L$ and $P_r^H = 1 - p_H$, and deposit rates (A.1) to self-selection constraints, (10) and (12), and to the objective function (13), we can rewrite the maximization problem with two self-selection constraints. The Lagrangian for maximization is

$$\text{(A.2)}\quad \Pi = p_L\left\{R_L - u^{-1}\left[\frac{u(r_f)-(1-p_L)u(x_L)}{p_L}\right]\right\} - (1-p_L)x_L$$

$$+\, p_H\left\{R_H - u^{-1}\left[\frac{u(r_f)-(1-p_H)u(x_H)}{p_H}\right]\right\} - (1-p_H)x_H$$

$$+\lambda_L\left\{p_L u^{-1}\left[\frac{u(r_f)-(1-p_L)u(x_H)}{p_L}\right] + (1-p_H)x_H\right.$$

$$\left. - p_L u^{-1}\left[\frac{u(r_f)-(1-p_L)u(x_L)}{p_L}\right] - (1-p_L)x_L\right\}$$

$$+\lambda_H\left\{p_H u^{-1}\left[\frac{u(r_f)-(1-p_H)u(x_L)}{p_H}\right] + (1-p_L)x_L\right.$$

$$\left. - p_H u^{-1}\left[\frac{u(r_f)-(1-p_H)u(x_H)}{p_H}\right] - (1-p_H)x_H\right\},$$

where λ_L and λ_H are Lagrange multipliers associated with self-selection constraints (10) and (12). First-order conditions for an interior solution, $\frac{\partial \Pi}{\partial x_L} = 0$ and $\frac{\partial \Pi}{\partial x_H} = 0$, can be given in simplified form as

$$\text{(A.3)}\quad \left[\frac{u'(x_L)}{u'(r_{LL})} - 1\right](1+\lambda_L) = \lambda_H\left[\frac{(1-p_H)u'(x_L)}{(1-p_L)u'(r_{HL})} - 1\right]$$

and

$$\text{(A.4)}\quad \left[\frac{u'(x_H)}{u'(r_{HH})} - 1\right](1+\lambda_H) = \lambda_L\left[\frac{(1-p_L)u'(x_H)}{(1-p_H)u'(r_{LH})} - 1\right]$$

We do not yet know whether λ_L and λ_H bind or not. Four cases arise.

First, one can establish that both self-selection constraints cannot be relaxed ($\lambda_L, \lambda_H = 0$). If $\lambda_L, \lambda_H = 0$, we see from (A.3) that $x_L = r_{LL}$ and from (A.4) that $x_H = r_{HH}$; both banks purchase full insurance, and $r_{LL} = r_{HH} = x_L = x_H = r_f$. The self-selection constraint for a high-risk bank then reduces to $p_H r_f + (1 - p_L)\, r_f < p_H r_f + (1 - p_H)\, r_f$. The total cost of attracting deposits is bigger if a high-risk bank chooses its own contract. A high-risk bank prefers the low-risk contract to its own contract, which contradicts the hypothesis $\lambda_H = 0$.

Next we show that the combination $\lambda_L > 0$, $\lambda_H = 0$, *leads to a violation of the self-selection constraint*. As in the first case, a low-risk bank gets full insurance (A.3). A high-risk bank also prefers the low-risk policy, which contradicts our hypothesis $\lambda_H = 0$.

Neither is the solution, $\lambda_L, \lambda_H > 0$ *possible*. Since the low-risk insurance is cheaper than the high-risk, a low-risk bank surely chooses its own contract when $x_L \geq x_H$. The self-selection constraint for a low-risk bank can bind only if $x_L < x_H$ (or $x_L = x_H = 0$). When both self-selection constraints bind, they can be written as

$$\text{(A.5)}\quad p_H r_{HL} + (1-p_L)x_L = p_H r_{HH} + (1-p_H)\,x_H,$$
$$p_L r_{LH} + (1-p_H)x_H = p_L r_{LL} + (1-p_L)\,x_L.$$

from which we get $p_L\,(r_{LL} - r_{LH}) = p_H\,(r_{HL} - r_{HH})$. We will show that this is not possible. We know that $x_L < x_H$, and so $r_{LL} > r_{LH}$, $r_{HL} > r_{HH}$. If $\partial/\partial p_i\, p_i\,[r_{iL}\,(p_i, x_L) - r_{iH}\,(p_i, x_H)] = 0$, then $p_L\,(r_{LL} - r_{LH}) = p_H\,(r_{HL} - r_{HH})$ as well. It is, however, easy to show that

(A.6) $$\frac{\partial}{\partial p_i} p_i [r_{iL}(p_i, x_L) - r_{iH}(p_i, x_H)] = [r_{iL} - r_{iH}] + \left\{ - \frac{u(r_f) - u(x_L)}{p_i u'(r_{iL})} + \frac{u(r_f) - u(x_H)}{p_i u'(r_{iH})} \right\} =$$

$$\frac{-1}{u'(r_{iL})} \left\{ \left[u(r_{iL}) - u'(r_{iL})[r_{iL} - r_{iH}] - u(r_{iH}) \right] + \left[u(x_H) - u(x_L) \right] + \left[[1 - \frac{u'(r_{iL})}{u'(r_{iH})}] \frac{u(r_f) - u(x_H)}{p_i} \right] \right\} < 0$$

The whole term is negative, since the three terms within the three big brackets are all positive. We see that $p_L\,(r_{LL} - r_{LH}) < p_H\,(r_{HL} - r_{HH})$, when $x_L < x_H$. Only if $x_L = x_H = 0$ do both constraints bind with equality: $p_L\,(r_{LL} - r_{LH}) = p_H\,(r_{HL} - r_{HH})$, since $r_{LL} = r_{LH}$ and $r_{LL} = r_{LH}$. In this case, however, no bank insures. Hence, both constraints cannot bind simultaneously.

Thus we must have $\lambda_L = 0$, $\lambda_H > 0$: only the self-selection constraint for a high-risk bank binds. Because $\lambda_L = 0$, the right-hand side of (A.4) is now zero. Because the left-hand side must also be zero, we have $x_H = r_{HH}$; a high-risk bank gets complete insurance and it pays risk-free interest on deposits, $x_H = r_{HH} = r_f$. Because the right-hand side of (A.3) is always positive, the left-hand side must also be positive and $u'\,(x_L)\,/\,u'\,(r_{LL}) > 1$. A low-risk bank partial coverage and it must pay higher interest on deposit than a high-risk bank, $x_L < r_f < r_L$. Q.E.D.

References

Aghion, P., and P. Bolton (1992). "An Incomplete Contracts Approach to Financial Contracting." *Review of Economic Studies* 59, 473–494.

Boot, A., and A. Thakor (1993). "Self-interested Bank Regulation." *American Economic Review* 83, 206–212.

Calomiris, C. (1990). "Is Deposit Insurance Necessary? A Historical Perspective." *Journal of Economic History* L (2), 283–298.

Calomiris, C., and B. Wilson (1998). Bank Capital and Portfolio Management: The 1930s "Capital Crunch" and Scramble to Shed Risk. NBER Working Paper 6649.

Chan, Y-S., S. Greenbaum, and A. Thakor (1992). "Is Fairly Priced Deposit Insurance Possible?" *The Journal of Finance* XLII (1), 227–245.

Chiesa, G. (2001). "Incentive-based Lending Capacity, Competition, and Regulation in Banking." *Journal of Financial Intermediation* 10, 28–53.

Cooper, R., and B. Hayes (1987). "Multi-period Insurance Contracts." *International Journal of Industrial Organisation* 5, 211–231.

Crocker, K., and A. Snow (1985). "The Efficiency of Competitive Equilibria in Insurance Markets with Asymmetric Information." *Journal of Public Economics* 26, 207–219.

– **(1986).** "The Efficiency Effects of Categorical Discrimination in the Insurance Industry." *Journal of Political Economy* 94(2), 321–344.

Dewatripont, M., and J. Tirole (1993). *The Prudental Regulation of Banks*. Cambridge: MIT Press.

Diamond, D. (1984). "Financial Intermediation and Delegated Monitoring." *Review of Economic Studies*, 393–414.

Dionne, G., and N. Doherty (1994). "Adverse Selection, Commitment, and Renegotiation: Extension to and Evidence from Insurance Markets." *Journal of Political Economy"*102(2), 209–235.

Flannery, M. (1998). "Using Market Information in Prudential Bank Supervision: A Review of the U.S. Empirical Evidence." *Journal of Money, Credit and Banking* 30(3), 273–305.

Freixas, X., and J-C. Rochet (1998). "Fair Pricing of Deposit Insurance. Is it possible? Yes. Is it Desirable? No." *Research in Economics* 52(3), 217–232.

– **(1997).** Microeconomics of Banking. Cambridge: MIT Press.

Garcia, G. (1998). "Deposit Insurance." In *Preventing Bank Crises*, 255–268. Eds. G. Caprio, W. Hunter, G. Kaufman and D. Leipziger. Washington: World Bank.

– **(1999).** Deposit Insurance: A Survey of Actual and Best Practices. IMF Working Paper 99/54.

Gunther, J., L. Hooks, and K. Robinson (2000). "Adverse Selection and Competing Deposit Insurance Systems in Pre-Depression Texas." *Journal of Financial Services Research* 17(3), 237–258.

Hyytinen, A., and T. Takalo (2002). "Enhancing Bank Transparency: A Re-assessment." *European Finance Review* (forthcoming).

John, K., A. Saunders, and L. Senbet (2000). "A Theory of Bank Regulation and Management Compensation." *Review of Financial Studies* 13(1), 95–125.

Jordan, J. (2000). "Depositor Discipline at Failing Banks." *New England Economic Review*, March/April, 15–28.

Jordan, J., J. Peek, and E. Rosengren (2000). "The Market Reaction to Disclosure of Supervisory Actions: Implications for Bank Transparency." *Journal of Financial Intermediation* 9, 298–319.

Matutes, C., and X. Vives (2000). "Imperfect Competition, Risk Taking, and Regulation in Banking." *European Economic Review* 44, 1–34.

Merton, R. (1977). "An Analytic Derivation of the Cost of Deposit Insurance and Loan Guarantees." *Journal of Banking and Finance* 1, 512–520.

Miyzaki, H. (1977). "The Rat Race and Internal Labor Markets." *Bell Journal of Economics* 8, 394–418.

Nagarajan, S., and C. Sealey (1998). "State-Contingent Regulatory Mechanisms and Fairly Priced Deposit Insurance." *Journal of Banking and Finance* 22, 1139–1156.

Niinimäki, J-P. (2001). "Intertemporal Diversification in Financial Intermediation." *Journal of Banking and Finance* 25, 965–991.

Rothschild M., and J. Stiglitz (1976). "Equilibrium in Insurance Markets: An Essay on the Economics of Imperfect Information." *Quarterly Journal of Economics* 90, 629–649.

Sironi, A. (2000). Testing for Market Discipline in the European Banking. The Federal Reserve Board Finance and Economics Discussion Series.

Stiglitz, J. (1977). "Monopoly, Nonlinear Pricing, and Imperfect Information: The Insurance Market." *Review of Economic Studies* 44, 407–430.

Vauhkonen, J. (2002). "An Incomplete Contracts Approach to Financial Contracting: a Comment." *Economics Bulletin* 7(1), 1–3.

Wheelock, D., and S. Kumbhakar (1995). "Which Banks Choose Deposit Insurance? Evidence of Adverse Selection and Moral Hazard in a Voluntary Insurance System." *Journal of Money, Credit and Banking* 27(1), 186–201.