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Liquidation Costs and Risk-Based Bank Capital

Helena M. Mullins
University of Oregon and University of British Columbia

and

David H. Pyle
University of California at Berkeley

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Abstract

Bank capital rules which do not recognize audit costs, liquidation costs and portfolio diversification can seriously underestimate actuarially fair capital requirements. If depositors do not have access to low cost alternatives, the effect of higher requirements can be imposed on them. Otherwise, they need absorb only costs associated with minimum-risk, minimum-cost assets. If borrowers have direct access to financial markets or can borrow from uninsured, less highly levered institutions, insured banks facing a fair risk-based capital requirement and fixed premium cannot attract them. A schedule of required capital and insurance premium pairs would allow banks to retain investment flexibility.
1. INTRODUCTION

Much of the theoretical literature on deposit guarantees has focused on their pricing and the feasibility of risk-adjusted insurance premia. In contrast, bank regulators have emphasized capital adequacy rules, most recently in the form of risk-based capital requirements. (See, for example, BIS (1988) and Federal Reserve (1989).) The purpose of this paper is to analyze the determinants of actuarially fair risk-based capital rules, focusing on the effects of audit costs, liquidation costs and portfolio diversification.

There are two possible interpretations of fair risk-based capital rules. These correspond to explicit and implicit insurance premium situations. The Federal Deposit Insurance Corporation currently charges U.S. commercial banks an explicit annual premium of twenty three cents per one hundred dollars of domestic deposits. In many European countries, there is no explicit premium, though government guarantees of bank deposits generally hold implicitly. With an implicit premium, fair risk-based capital rules ensure that the deposit guarantor's liability is unaffected by the composition of the bank's asset portfolio and leverage. We focus here on the explicit premium case. In this case, we interpret fair capital rules to be those which guarantee that the insurer's liability is equal to the premium charged. The analysis extends straightforwardly to the implicit premium case.

We analyze risk-based capital rules in a single period model which relies on Black and Scholes' (1973) option valuation. The stochastic variable in the model is the market value of a bank's asset portfolio at the end of the period when an audit by the insurer takes place. The bank is financed with deposits and capital (net worth). If the market value of the bank's assets is less than the depositors' claims, the insurer pays off the depositors in full and takes claim to the bank's assets which it then sells. We focus on the effect of audit costs and liquidation costs on the required ex-ante capital level imposed by the insurer.

We assume that the insurer in setting the capital requirement, at the start of the period, can determine the capital risk of the bank's asset portfolio and that this risk does not
change over the time until audit. When an audit takes place, the insurer assesses the current market value, incurring costs in the process. We assume that these audit costs are paid by the insurer at the time of audit. They are part of the insurer’s liability in insuring the bank’s depositors and are taken into account by the insurer in setting capital requirements.7

If at the time of audit the insurer finds that the value of the bank’s assets are less than promised payments to depositors, we assume that the insurer takes over the bank. Subsequently, it tries to sell the bank’s assets or arranges for the failed bank to be taken over by another bank. In this process, the insurer incurs liquidation costs. Liquidation costs arise because of difficulties in transferring information and management expertise from the bank to the insurer and on to a third party. Like audit costs, liquidation costs affect the insurer’s liability and must be taken into account in setting fair capital requirements.

Convincing empirical evidence that liquidation costs are significant has been presented by Bovenzi and Murton (1990), James (1991) and Brown and Epstein (1992). Asset liquidation costs fall into two general categories, liquidation expenses and discounts from the “going-concern” values of assets when they are sold to third parties. Using recent data on FDIC liquidations, Brown and Epstein provide estimates of the liquidation expenses for six asset categories.8 The following table is adapted from their study.

<table>
<thead>
<tr>
<th>Asset Type</th>
<th>Liquidation Expense (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installment Loans</td>
<td>11.5</td>
</tr>
<tr>
<td>Commercial Loans</td>
<td>5.9</td>
</tr>
<tr>
<td>Securities</td>
<td>0.0</td>
</tr>
<tr>
<td>Mortgages</td>
<td>2.7</td>
</tr>
<tr>
<td>Owned Real Estate</td>
<td>17.2</td>
</tr>
<tr>
<td>Other Assets</td>
<td>5.9</td>
</tr>
</tbody>
</table>

Unfortunately, the available data do not provide information on the typical shortfall, if any, between the value of assets on a going-concern basis and the prices realized in liquidation, a figure that, if available, would be added to the liquidation expenses to form total liquidation
costs. We show that the use of risk-based capital requirements that do not explicitly take into account the potential effect of liquidation costs can lead to serious under-estimation of the fair capital required.

A feature of the current risk-based capital rules is a capital-to-asset ratio requirement that is a weighted average of the required ratios for various categories of the underlying assets. The weights are given by the proportions invested in each category. Thus, the current requirements do not take account of portfolio diversification. Not surprisingly, our analysis shows that by not taking asset return covariances into account the new requirements tend to overestimate the fair capital requirement. Furthermore, we establish that the consequence of this depends on the interaction between diversification effects and the liquidation costs. We show that the effect of asset return covariances in reducing fair capital requirements is partially offset by the effects of large liquidation costs.

In the process of examining audit costs, liquidation costs and diversification effects, we analyze the pricing of deposits and assets by a bank facing a fair capital requirement. By pricing we mean the interest rates promised to depositors and charged to borrowers. This analysis leads us to examine the type of investments undertaken by such a bank. We conclude that if fair risk-based capital requirements and a fixed deposit insurance premium were imposed on banks in a competitive banking market, their asset choices would be drawn from a smaller set than U.S. banks typically draw on currently, a set comprised more of low risk assets. However, if the insurance system was based on a combined risk-based capital and insurance premium requirement, banks could retain their investment flexibility. We show that by choosing to hold more capital, banks can reduce the effects of liquidation costs and offer better terms on their loans.

In Section 2, we present the basic framework for our analysis. We introduce audit costs that vary across asset type into the model in Section 3 and study their implications for the pricing of bank deposits and the choice of bank investments. Liquidation costs are the focus of Section 4. Again we allow these costs to be different for different asset types (Section
4.1. In Section 4.2, we examine the implications of these liquidation costs for the pricing of bank deposits and assets, and discuss their effects on bank investment decisions. Section 5 contains an examination of the impact of portfolio diversification and its implications for the significance of liquidation costs. We conclude the paper in Section 6.

2. BASIC FRAMEWORK

We analyze bank capital requirements in a single period model. At time $t = 0$, the bank raises $D_0$ in deposits, $E_0$ in equity and pays out $P_0$ in an insurance premium. Thus,

$$V_0 = D_0 + E_0 - P_0$$

where $V_0$ is the value of the bank's assets. At time $t = 1$, an audit takes place to determine the composition of the bank's asset portfolio and assess its current market value. If the value of the bank's assets, $V_1$, is less than the promised payments to the depositors, $D_1$, the insurer pays out $(D_1 - V_1)$. Otherwise, the depositors are paid by the equity holders who retain any residual.

Define $P_0(V_0, D_1, \sigma_V)$ to be the Black and Scholes' (1973) value of the put option, written on the bank's assets and with an exercise price equal to the promised payments to the depositors, which the insurer has effectively written to the shareholders. Similarly, define $E_0(V_0, D_1, \sigma_V)$ to be the Black-Scholes value of the call option effectively purchased by the shareholders of the bank. We impose two conditions on our model

$$P_0 = P_0(V_0, D_1, \sigma_V) \quad (1a)$$

$$E_0 = E_0(V_0, D_1, \sigma_V) \quad (2a)$$

where $\sigma_V$ is the standard deviation of the return on the bank's assets. Equation (1a) requires that the deposit insurance premium be actuarially fair. The dollar amount of the premium paid by the bank, $P_0$, is set equal to the current value of the insurer's expected future liability. Equation (2a) is motivated by the assumption that there is free entry into the
banking industry. It states that equity is a zero net present value investment, i.e., the dollar amount invested by the shareholders, $E_0$, is equal to the current value of the call option which they effectively purchase from the debtholders.

Equations (1a) and (2a) can be expanded and rewritten in terms of the current premium per dollar of deposits, $p_0$, and the current capital-to-deposit ratio, $k_0$.

\[ p_0 = e^{-\mu_D}N(-y + \sigma_V) - (1 + k_0 - p_0)N(-y) \quad (1b) \]

\[ k_0 = (1 + k_0 - p_0)N(y) - e^{-\mu_D}N(y - \sigma_V) \quad (2b) \]

where

\[ y \equiv \frac{\ln(1 + k_0 - p_0) + \mu_D}{\sigma_V} + \frac{\sigma_V}{2} \]

\[ p_0 \equiv P_0/D_0 \]

\[ k_0 \equiv E_0/D_0 \]

and

\[ \mu_D \equiv \tau_f - \tau_D. \]

$\mu_D$ is the deposit rate spread, i.e., the spread between the risk-free rate and the promised rate on deposits. $N(.)$ is the cumulative probability for a standard normal random variable.

In the above system, we set $p_0$ equal to a fixed premium (e.g., 0.0023, the current premium per dollar of deposits imposed on U.S. commercial banks), and choose a specific value for $\sigma_V$. We then solve equations (1b) and (2b) simultaneously to derive the fair capital-to-deposit ratio, $k^*_0(\sigma_V)$, and the deposit rate spread, $\mu^*_D(\sigma_V)$, that is consistent with zero net present value equity investment. Table 1a presents values for these variables when $\sigma_V$ ranges between one percent and ten percent. As expected, $k^*_0$ is increasing in $\sigma_V$. As is well-known, given a fixed premium, the insurer must impose a capital requirement which is increasing in asset risk in order to keep its liability consistent with that fixed premium. The capital-to-deposit ratio which achieves this for a given $\sigma_V$ value is what we are calling the fair capital ratio for that level.
3. THE EFFECT OF AUDIT COSTS

We assume that an audit takes place for certain (independent of the bank's capital ratio, for example) at time $t = 1$. The purpose of the audit is to determine the current market value of the bank's total asset portfolio. We assume that total audit costs are proportional to the size of the bank's total asset portfolio, $V_0$. Thus,

$$\text{total audit costs} = aV_0 = a(D_0 + E_0 - P_0)$$

and

$$\text{audit costs per dollar of deposits} = a(1 + k_0 - p_0).$$

We also assume that audit costs can vary across asset types so that a given bank's audit cost factor will depend on the type of asset it holds. In particular, audit costs will be greater for those banks investing in assets with a more complex return structure (e.g., assets with imbedded options), non-marketable assets that do not have close market substitutes, or assets with values depending heavily on private information.

When we incorporate audit costs into the framework summarized by equations (1b) and (2b), and assume that audit costs are paid by the insurer, we get the following conditions

$$p_0 = e^{-\mu_D}N(-y + \sigma v) - (1 + k_0 - p_0)N(-y) + a(1 + k_0 - p_0)$$ (1c)

$$k_0 = (1 + k_0 - p_0)N(y) - e^{-\mu_D}N(y - \sigma v).$$ (2c)

Notice that since the audit costs do not enter directly into the equity value, equation (2c) is the same as equation (2b).

Table 1b presents the solutions to equations (1c) and (2c). We consider three possible values for the proportional audit costs. The lowest audit costs of 5 basis points per dollar of assets can be taken to reflect the costs of auditing a bank that invests mostly in marketable securities. Higher audit costs of 10 and 15 basis points per dollar of assets arise for banks that invest in assets with more complex cash flows and less transparent values. We also
consider a range of values for the volatility of the bank's assets, ranging from one percent to 10 percent. The resulting matrix illustrates the effects of different audit cost and volatility values on fair capital-to-deposit ratios and equilibrium deposit rate spreads.

Table 1b shows that, from an individual bank's perspective, both the fair capital-to-deposit ratio and the equilibrium (zero profit) deposit rate spread increase with proportional audit costs (for a given volatility level) and with asset risk (for a given audit cost level). As may be seen by comparing the values of $k_0$ in tables 1a and 1b, when the insurance premium is fixed the insurer must increase the bank's required capital to keep it consistent with the combined effects of asset risk and audit costs. Given the resulting higher level of capital for higher audit costs, the bank is now paying an implicit insurance premium greater than the one it would pay in the absence of those costs. To maintain the shareholders' zero net present value position, the bank must find a way to compensate for the higher capital requirement burden induced by the audit costs. It does so, if possible, by imposing a higher deposit spread on depositors. The most important effect on the magnitude of a bank's desired deposit rate spread results from differences in what it costs the insurer to value the bank's assets. The increase in deposit rate spread with asset risk is less pronounced and results from spreading a given total audit cost across a deposit base that must decrease as risk-based capital increases.\textsuperscript{11}

The above findings contrast with those reported by Merton (1978) and Pyle (1986a). They assume audit costs to be proportional to deposits and find the equilibrium deposit spread to be equal to the amount of audit cost per dollar of deposits, for all exogenous levels of asset risk. When we introduce audit costs that are proportional to deposits into the system summarized by equations (1b) and (2b), our model also yields this result. Such result depends entirely on the assumption that audit costs are directly proportional to the amount of deposits and independent of asset type. This assumption was necessary in the models presented by Merton (1978) and Pyle (1986a) in order to obtain tractable differential equations. We can relax this assumption and also allow audit costs to vary with the nature
of the assets being valued in the audit.

Whether banks will be able to pass all audit costs onto the depositors depends on the nature of banking markets. If all banks hold asset portfolios subject to the same audit cost factor and the same risk, and if depositors do not have access to any other investment channels, then a single equilibrium deposit spread is imposed on and borne by all depositors. However, if depositors are free to place their deposits with a bank that invests in minimum-risk, minimum-audit-cost assets and if there is free entry into banking markets, banks that hold riskier assets or higher audit-cost assets or both will be unable to attract deposits at spreads higher than those associated with minimum-risk, minimum-audit-cost assets. Furthermore, if depositors have direct access to minimum-risk assets, the minimum spread will be determined by depositors’ direct investment transaction costs.

This result has strong implications regarding the assets held by insured banks that are subjected to fair risk-based capital requirements in a competitive banking market. Such banks would be forced to hold only those assets in which they and the insurer combined have a cost or return advantage over other investors. Minimum insurer audit costs and minimum risk would be associated with default-free securities and deposit-maturity-matching strategies. Default-free securities held in non-maturity matching strategies, default-free securities with imbedded options, and default-prone securities would result in higher equilibrium deposit spreads. Unless the markets for these securities were inefficient and banks had a comparative advantage in exploiting those inefficiencies, they could not be held profitably.¹²

As a specific example of the above, it seems doubtful that insured banks in a deposit market subject to free-entry and facing a fair risk-based capital requirement could hold mortgage-backed securities. The value of these securities depends on the value of imbedded prepayment options which in turn depends on specific characteristics of the underlying mortgage pool. The insurer’s audit cost in identifying the characteristics of the underlying collateral in order to price mortgage-backed securities and assess their riskiness is certain to be greater than the audit cost of a portfolio of Treasury Bills and it seems doubtful that
banks could have a return advantage for holding mortgage-backed securities. In contrast, it is more believable that a bank and its insurer could have a comparative advantage in holding various types of non-market instruments such as loans.

4. THE EFFECT OF LIQUIDATION COSTS

4.1 MODELING LIQUIDATION COSTS

Previous option-theoretic analyses of deposit insurance pricing have assumed that when a bank is found to be insolvent the insurer can realize the full value of the bank’s assets. The value realized by the insurer at that time is assumed to be the value that would prevail if the bank had been found solvent and continued in operation. We will call this the “going-concern” value. There are reasons to believe that realization of the going-concern value by the insurer will not be possible for all bank assets. Liquidation costs will accompany the transfer of assets from the bank to the insurer or to an acquiring firm. The purpose of this section is to analyze the effects of these liquidation costs.

The primary source of liquidation costs is the difficulty and cost in transferring information. The insurer does not have as detailed information as the manager about the bank’s borrowers or the nature of the contracts with those borrowers. Acquiring this information is costly for the insurer and for any third party to whom the assets might be sold. Further, if the insurer is forced to continue operating the assets, it will bear added costs unless it can costlessly capture the necessary information and skills for managing the assets to yield their going-concern values. This consideration becomes more serious the longer the insurer has to manage the bank’s assets and the greater the specialized information involved. Also, the sale of a large volume of assets into a thin market of buyers who are aware of the insurer’s predicament may exacerbate the adverse effects on realized values. Finally, there may be insurer taxes, legal costs, and brokerage fees in bank insolvencies.

It is important to emphasize that liquidation costs, in this context, do not refer to the loan
losses that exist when a bank fails. Such losses are captured in the stochastic behavior of the asset returns, summarized in \( \sigma_Y \). Neither are we referring to past losses on assets unrealized due to failure to mark assets to market. Rather, we are concerned with the additional costs for liquidating performing and non-performing assets that are value-dependent on information and managerial skills.

Empirical evidence that liquidation costs can be significant has been presented by Bovenzi and Murton (1990), James (1991), and Brown and Epstein (1992). James estimates that total “failure resolution costs” averaged 30.5 percent of assets (measured at book value) across 412 banks which failed during 1985-88. Using more recent data from 594 bank failures in the period from 1986 to 1990, Brown and Epstein estimate total liquidation costs that average 49.9 percent of asset book value. Since costs are measured from a book value base in both cases, these estimates tend to overstate liquidation costs for our purposes. Unfortunately, the authors find it impossible to decompose these total costs into unrealized losses and liquidation costs. This is because banks have not been required to mark their assets to market and insurer-mandated asset write-downs have fallen far short of a proper adjustment to going-concern values. Brown and Epstein (Table 3) do provide some estimates of the FDIC’s liquidation expenses across six asset categories. Their findings, which we summarized in the table in the Introduction, provide us with lower bounds, ranging from zero percent to over 17 percent, for liquidation costs.$^{13}$

Shleifer and Vishny (1992) also analyze liquidation costs. They provide an extensive discussion of reasons why assets will sell at “prices below values in best use” when liquidated. These include the fact that the best qualified buyers are likely to be in distress too, that government and regulatory restraints may preclude intra-industry buyers, and the effects of agency costs and discounts due to the fear of overpaying (information asymmetries) when the assets must be sold to industry outsiders.

This motivates our introduction of liquidation costs into the model summarized by equations (1c) and (2c). Liquidation costs are incurred when the insurer takes over the bank
at the time of audit because the going-concern value of the bank is less than the promised payments to depositors. We allow for the possibility that the going-concern value of the bank may be so low \((V_1 \leq \underline{V})\) that it is not worthwhile for the insurer to take over these assets and try to liquidate them. At \(\underline{V}\), the liquidation costs completely absorb the going-concern value. Thus, for \(V_1 \leq \underline{V}\), the insurer will not liquidate the bank's assets (and hence liquidation costs will be zero) but will simply pay out the promised payments to depositors.

Within this structure, we assume liquidation costs of the following form

\[
\text{total liquidation costs} = \begin{cases} 
  l_0 V_0 e^{\tau} + l_1 (V_0 e^{\tau} - V_1) & \underline{V} < V_1 < D_1 \\
  0 & \text{otherwise}
\end{cases}
\]  

(3)

Liquidation costs have two components. The first component is proportional to the bank's asset size (as measured by \(V_0\)) and captures legal and administrative costs plus a component of the buyer's discount from going-concern value, to the extent that such a discount is independent of the level of insolvency.\(^{14}\) The buyer's total discount must cover the buyer's evaluation cost, the buyer's uncertainty about the going-concern value (winner's curse and agency cost effects), and the effects of industry distress on realizable asset values. The second component which increases as the level of insolvency increases (up to \(\underline{V}\)) reflects the likelihood that some of these determinants of the buyer's discounts will have stronger effects the more the bank's assets are below book value.

To ensure that liquidation costs are not negative, \((l_0 + l_1)\) and \(l_0\) in equation (3) cannot be negative. It is intuitively appealing to think of liquidation costs increasing with the shortfall between the initial book value of the bank's assets and their going-concern value, i.e., a positive value for \(l_1\). Alternatively, the case where \(l_1\) is zero while \(l_0\) is positive focuses on fixed liquidation costs. In this case, we can think of liquidation costs depending on bank size but not varying with bank asset value. In general, we expect \(l_1\) to be positive but small relative to \(l_0\), given that \(l_0\) includes a significant part of the buyer's discount as well as the administrative and legal costs.\(^{15}\)

Figure 1 illustrates the insurer's liability when there are liquidation costs of the form
summarized by equation (3), where both \( l_0 \) and \( l_1 \) are positive. Through the basic provision of deposit insurance, the insurer effectively sells a put option to the equity holders, with exercise price equal to the promised payments to depositors. In the presence of liquidation costs, and ignoring for the moment any abandoning of worthless assets, the insurer sells an extra \( l_1 \) puts, with exercise price \( D_1 \), and issues a security that pays \(((l_0 + l_1)V_0e^{r't} - l_1D_1)\) when \( V_t \leq D_1 \) and zero otherwise. (See Appendix for valuation of such a security.) If the insurer does abandon worthless assets, i.e., assets having a going-concern value of \( V \) or less, the insurer avoids liquidation costs and generates some savings. These savings are equivalent to the value of \((1 + l_1)\) puts, with exercise price \( V \).

The value of the insurer’s liability is increasing in the risk of the bank’s assets. At higher levels of asset risk, the value of the \((1 + l_1)\) puts sold increases. The value of the extra security issued also increases with asset risk since a payout of \(((l_0 + l_1)V_0e^{r't} - l_1D_1)\) by the insurer becomes more likely. It also becomes more likely that the going-concern value will be less than \( V \), and thus more likely that the insurer will realize savings from abandoning worthless assets. This latter effect is of second order importance, however.

In section 3, we assumed that audit costs vary according to asset type. It is also reasonable to expect liquidation costs to depend on asset type. This is supported by the recent evidence presented by Brown and Epstein (1992). Furthermore, audit costs are likely to be positively related to liquidation costs, because of the mutual dependence on asset type. We can take this into account by extending our assumption regarding audit costs as follows

\[
\text{total audit costs} = aV_0 = (b + c.l_0)V_0
\]  

(4)

On the basis of the above structure on audit costs and liquidation costs, we can now rewrite the fair deposit insurance condition and the zero net present value condition which describe our model.
\[ p_0 = (1 + l_1)[e^{-\mu_D}N(-y + \sigma_V) - (1 + k_0 - p_0)N(-y)] \\
+ ((l_0 + l_1)(1 + k_0 - p_0) - l_1e^{-\mu_D})N(-y + \sigma_V) \\
- [((l_0 + l_1)(1 + k_0 - p_0)N(-x + \sigma_V) - (1 + l_1)(1 + k_0 - p_0)N(-x)] \\
+ (b + c.l_0)(1 + k_0 - p_0) \quad (1d) \\
k_0 = (1 + k_0 - p_0)N(y - \sigma_V) \quad (2d) \\
\]

where \[
y = \frac{\ln(1 + k_0 - p_0) + \mu_D}{\sigma_V} + \frac{\sigma_V}{2} \]

\[
x = \frac{\ln((1 + l_1)/(l_0 + l_1))}{\sigma_V} + \frac{\sigma_V}{2} \]

and \[
\mu_D \equiv r_f - r_D. \]

The first term in equation (1d) is the value of the one put option which the insurer writes when providing deposit insurance plus the value of the extra \( l_1 \) puts effectively written when there are liquidation costs. The second term in this equation is the value of the security that pays \(((l_0 + l_1)V_0e^{r_f} - l_1D_1)\) when \(V_1 \leq D_1\). Finally, the terms in the second square brackets refer to the savings that the insurer realizes by abandoning the bank's assets when they are worthless (i.e., when the going-concern value does not even cover liquidation costs). Note that the zero net present value condition (2d) is not directly affected by liquidation costs.

Figure 2 shows the effect of our linear specification of liquidation costs on the fair capital-to-deposit ratio. We consider three possible sets of values for \( l_0 \) and \( l_1 \) and, under the assumption that \( \sigma = 0.0005 + 0.01l_0 \), we have three corresponding values for audit costs per dollar of assets.\(^{16}\) Referring again to the evidence presented by Brown and Epstein (1992), we can think of the above three cases as corresponding to situations where the majority of a bank’s investments are in securities or in assets such as commercial loans or installment loans.

From Figure 2, we can see that the capital requirement schedule, as a function of asset risk, moves up as liquidation costs increase. The insurer, who bears the liquidation costs
directly, imposes an indirect liquidation cost on the bank by requiring a higher capital ratio. It is clear that regulatory capital rules which do not take account of liquidation costs can lead to serious under-estimation of the fair capital requirement. Furthermore, Figure 2 shows that this under-estimation is more important when asset risk is high. This is consistent with the fact that the insurer’s extra liability in the presence of liquidation costs is greater at higher asset risk levels.

4.2 IMPLICATIONS FOR PRICING OF BANK’S DEPOSITS AND ASSETS

We saw in Section 3 that when deposit insurance is fairly priced, capital requirements reflect all costs borne by the insurer. Thus, if the insurer pays directly for audit costs, for example, these are passed on to the bank through a higher capital requirement. The same is true for liquidation costs, as Figure 2 demonstrates. To avoid a negative net present value position, a bank in this situation must find a way to pass the burden of the higher capital requirements on to its customers. Figure 3a illustrates how this would affect the deposit rate spread, \( r_f - r_D \), if the bank were to try to pass the cost of higher required capital on to its depositors. The greater the costs, the larger the deposit rate spread. However, as argued in Section 3, the scope for passing the burden of higher required capital on to the bank’s depositors is expected to be limited by the availability of low audit cost alternatives. Therefore, we turn to consideration of the possibility of charging the bank’s borrowers the costs of the additional required capital.

Higher capital requirements arise because of costs associated with the bank’s investments. A bank’s role is generally perceived to be that of accepting deposits and providing loans. The specialized information and skill involved in managing this loan portfolio implies that significant audit costs and liquidation costs are likely to occur. For the bank facing fair capital requirements to survive, its borrowers must bear the burden of these costs. It will be possible for a bank to pass on these costs only if all institutions serving those borrowers face the same or greater liquidation and audit costs for the type of assets it holds, and if borrowers cannot escape to some more attractive alternative. We focus on this situation for
A positive differential between the going-concern value of a bank's assets and the price that the bank is willing to pay to borrowers (for the bond or loan that is effectively issued by the borrowers to the bank) is evidence that the bank is passing costs on to its borrowers. Only in the case where there are no liquidation costs and no excess audit costs will the purchase price that a bank advances to borrowers be equal to the going-concern value of the borrowers' liability to the bank. We can think of this in more specific terms by examining the spread between the expected return on the loan portfolio and the risk-free rate. Assume that the insurer and the bank are risk neutral. In this case, we can characterize our model by the following two equations

\[ p_0 = (1 + l_1)[e^{-\mu_D} N(-y + \sigma_V) - (1 + k_0 - p_0)e^{\mu_L} N(-y)] + ((l_0 + l_1)(1 + k_0 - p_0) - l_1 e^{-\mu_D}) N(-y + \sigma_V) - ((l_0 + l_1)(1 + k_0 - p_0)N(-x + \sigma_V) - (1 + l_1)(1 + k_0 - p_0)e^{\mu_L} N(-x)] + a.(1 + k_0 - p_0) \]  

(5)

\[ k_0 = (1 + k_0 - p_0)e^{\mu_L} N(y) - e^{-\mu_D} N(y - \sigma_V) \]  

(6)

where

\[ y \equiv \frac{\ln(1 + k_0 - p_0) + \mu_D + \mu_L}{\sigma_V} + \frac{\sigma_V}{2} \]

\[ x \equiv \frac{\ln((1 + l_1)/(l_0 + l_1))}{\sigma_V} + \frac{\sigma_V}{2} \]

\[ \mu_D \equiv r_f - r_D \]

and

\[ \mu_L \equiv r_L - r_f \]

\( r_L \) is the expected return on the loan portfolio. We will refer to \( \mu_L \) as the loan rate spread.

To solve this system, we assume that the deposit rate spread, \( \mu_D^* \), is set exogenously at the rate charged by an institution investing only in minimum-risk, minimum-audit-cost
securities. From our discussion in Section 3, we know that, with free entry, such an institution would set the minimum deposit rate spread.

We can solve equations (5) and (6) for the fair capital ratio, \( k^*_H(\sigma_V) \), and the equilibrium spread on the loan portfolio, \( \mu_L^*(\sigma_V) \). As before, we find that higher liquidation costs lead to a higher capital ratio (see Figure 2). Liquidation costs increase the insurer's liability. Thus, given that there is a fixed deposit insurance premium, the insurer must impose a higher capital requirement on the bank to keep its liability consistent with that fixed premium. The bank in turn, faced with a higher risk-based cum liquidation cost-based capital ratio, must find a way to make up for this cost. It does so by increasing the spread on the loan portfolio (see Figure 3b).

We can see from Figure 3b that when there are liquidation costs and the insurance premium is fixed, the loan rate spread is lower at higher risk levels.\(^{19}\) This can be explained by recognizing that the risk level has both a direct effect and an indirect effect. Higher risk means that the insurer's extra liability due to liquidation costs is higher which puts upward pressure on the loan rate spread (direct effect). Higher risk also means a higher capital requirement, and this reduces the value of the insurer's extra liability and has a downward effect on the loan rate spread (indirect effect). The overall outcome depends on the relative magnitudes of the change in risk and the corresponding change in fair capital. Capital is a convex function of asset risk (see Figure 2). Thus, the percentage increase in capital will be larger than the percentage increase in risk. This means that the indirect effect above will dominate. Thus, the insurer's extra liability due to liquidation costs will be smaller at higher levels of risk, and liquidation costs will be passed on to borrowers in the form of a smaller loan spread.\(^{20}\)

The above conclusions hold for banks facing a fixed insurance premium and fair risk-based capital requirements and depend on the assumption that borrowers have no alternative funding possibilities. Now, suppose that borrowers have access to lenders other than banks. An insured bank subject to fair risk-based capital requirements will be able to purchase assets
carrying liquidation costs and excess audit costs only if the combined effects of those costs on the purchase price is less than borrower's transaction costs for raising funds directly in the financial markets or from uninsured financial institutions. With free entry into lending, such assets could be held by an uninsured institution with less leverage (e.g., a mutual fund) for which the likelihood of insolvency and the corresponding liquidation costs would be significantly smaller. The conclusion one is led to is that the asset choices of banks subject to fair risk-based capital requirements and a fixed insurance premium would be a sub-set of those currently held.

It is important to recognize that this conclusion is dependent on a deposit insurance structure in which there is no tradeoff between required risk-based capital and the insurance premium. Consider the effects of dropping the assumption of a single fixed insurance premium. Suppose instead that banks holding assets in a given risk class and with given insurer-borne liquidation costs were offered a schedule of required capital and insurance premium pairs. Each capital/premium combination would have to satisfy the insurer’s fair capital constraint, with higher capital requirements leading to lower premiums. Banks choosing to hold more capital would be able to offer better terms on loans subject to insurer liquidation costs. With free entry into banking, loan rate spreads due to insurer-borne liquidation costs would become diminishingly small. Figure 4 shows this important effect and suggests that taking the “either/or” view of risk-based capital versus risk-based insurance premiums precludes the potential policy advantages of using both instruments. This result lends support to proposals, such as the new FDIC assessment schedule, that employ a risk-based capital requirement with a scale of insurance premiums that decline with decreases in leverage, asset risk held constant.

5. THE EFFECT OF PORTFOLIO DIVERSIFICATION

We saw earlier that the equilibrium capital ratio is increasing in audit costs, liquidation costs, and asset risk, for reasonable parameter values. These results suggest a trade-off, in terms of required capital, that may exist between diversification on the one hand and the
liquidation and audit costs on the other. If required capital is an increasing function of asset volatility, the fair capital ratio will tend to be lower if a bank adds assets with returns that are imperfectly correlated with existing returns rather than assets with the same return variance but higher return correlations. However, suppose this diversification involves adding assets with greater liquidation costs and/or greater audit costs. Then the fair capital ratio will tend to increase. An analysis of the relative importance of portfolio diversification and liquidation costs is the subject of this section of the paper.

We move to the situation where we assume that the bank holds a portfolio of two assets. A proportion \( \alpha \) is invested in asset 1 and \( (1 - \alpha) \) in asset 2. Asset 2 is assumed to be an exchange market asset carrying zero liquidation costs. We allow asset 1 to carry positive liquidation costs and we assume that the variance of the returns on this asset is greater. \( \rho \) is the correlation coefficient between the returns on the assets.

Figures 5a and 5b show the relation between the fair capital ratio and the proportion held in asset 1, for different values of the correlation coefficient. Figure 5a highlights the effect of diversification on the fair capital ratio when liquidation costs are zero for both assets. We can see that imperfect asset return correlations have the anticipated effect of lowering the required capital.

If portfolio diversification were not taken into account, the capital requirement would simply be a linear combination of the capital requirements for the two assets in the portfolio, weighted according to the proportion invested in each asset. We can represent this by the line \( AB \). Figure 5a shows that capital requirements which do not take account of diversification will result in an unnecessarily heavy burden on a bank and the extent of over-burdening, will obviously depend on the size of \( \rho \). In reality, bank asset returns are likely to be highly correlated due to their common dependence on interest rates and the level of economic activity.

Figure 5b examines the effects of liquidation costs and the interplay between liquidation
costs and diversification effects. We include a line $AC$ which depicts a capital rule that takes into account asset variances and liquidation costs but not diversification effects. (The extreme points of such a line, at $\alpha = 0$ and $\alpha = 1$, are given by the fair capital ratios for each asset when the bank's whole portfolio is invested in that asset, i.e., when diversification is assumed to be irrelevant.) From this we see that if a capital requirement corresponding to the line $AC$ were imposed, the extent of over-burdening of the banks is consistently lower than in the zero liquidation costs case. Indeed, there are now realistic $(\alpha, \rho)$ values at which underestimation of the fair capital ratio by the regulators occurs. The effect of imperfect correlation is to reduce the discrepancy between the linear rule and the correct fair capital-to-deposit ratio at first but then to increase it. Diversification reduces the importance of asset volatility in determining the fair amount of capital and increases the importance of the more linear effects of liquidation costs.

We could consider also a capital rule that takes into account only asset variances, ignoring liquidation costs and diversification. This is the same as the line $AB$ in Figure 5a, and is inserted again in Figure 5b. It is clear that, relative to the rule $AB$, the findings above are even more pronounced.

6. CONCLUSIONS

Our analysis in this paper examines the effect of liquidation costs on fair risk-based capital, allowing also for the effects of audit costs and portfolio diversification. We show that liquidation costs can significantly increase the capital level that is necessary to guarantee that the insurer's liability is not greater than a given fixed deposit insurance premium. A failure to recognize this would lead underestimation of the fair capital ratio and leave the insurer over-exposed to banks' risk taking. Furthermore, marking banks' assets to market or timely bank closure by regulators do not eliminate the effect of liquidation costs. It is necessary that liquidation costs be explicitly factored into the specification of risk-based capital requirements.
There are important implications regarding sustainable banking activities if required capital ratios and insurance premiums correctly reflect the combined effects of asset risk, audit costs and liquidation costs, including the following. With free entry into deposit services supply, depositors need only absorb the audit costs associated with minimum-risk, minimum-audit-cost assets (e.g., short-term government debt). Where borrowers have direct access to capital markets or can borrow from uninsured, less highly levered institutions, insured banks, facing a fixed premium and fair risk-based capital requirements, will only be able to hold assets carrying liquidation costs when there are specific efficiencies inherent in the insured bank structure. However, where there is free entry into bank lending and deposit services supply, and banks can chose among fair capital/insurance premium pairs, loan market competition will result in bank capital positions that make the insurer's liquidation cost liability diminishingly small. This result lends support to proposals to employ a schedule of required risk-based capital and insurance premium pairs.
ENDNOTES

1. The new rules specify a required capital level for each of a number of different categories of assets. The categorization is based on a broad assessment of credit risk. There are many grounds on which these guidelines can and have been criticized. One of the most important criticisms is that the BIS (1988) guidelines fail to incorporate interest rate risk as an explicit determinant of the risk-based capital requirements. As Kane (1985), Pyle (1986b) and others have pointed out, failure to deal with the interest rate risk inherent in Savings and Loan operations in the United States is the original cause of the Savings and Loan crisis.

2. While we have chosen to focus on the determinants of risk-based capital rules, the approach we have taken can be and has been used to analyze other risk-related insurer liability control mechanisms, for example, risk-based deposit premiums.

3. In September 1992, the FDIC and the Federal Reserve Board announced new capital rules that will come into effect on January 1, 1993. According to these rules, the premium charged to banks will depend on the bank's capitalization (well-capitalized, adequately-capitalized or under-capitalized) and the supervisor's rating of the bank (A, B or C). The premiums, per one hundred dollars of domestic deposits, for the nine possible classifications will vary from 23 cents to 31 cents. Thus, all banks except those with 'A' ratings and considered well-capitalized face premium increases. See BNA (1992).

4. The Black-Scholes model of deposit guarantees abstracts from some important aspects of this process and maintains strong assumptions regarding the efficiency of asset markets, the distribution of asset returns, and other important factors. Nonetheless, we believe the model is capable of giving useful qualitative insights on important and somewhat neglected determinants of risk-based capital requirements.

5. For our model, it is convenient to define the capital requirement in terms of the ex-ante capital-to-deposit ratio, where this ratio is measured using market values, rather than the more conventional book value capital-to-asset ratio. However, the results may be interpreted
in terms of the more conventional measure since the capital-to-deposits ratio is a monotonically increasing function of the market value capital-to-asset ratio and, barring unusual accounting rules, the \textit{ex-ante} book ratios and market ratios will be equal under the model assumptions.

6. We assume that the insurer can assess the bank's risk without error. See the analysis by Flannery (1991) of the case where the insurer measures the bank's risk with error.

7. Some of these cost may occur at the start of the period, e.g., costs of assessing the bank's asset risk, but since their occurrence and size is independent of the state of nature at the audit date they may be treated as occurring at the audit date without loss of generality.

8. Liquidation expenses in the Brown and Epstein (1992) study include taxes, asset-related legal fees, brokerage fees, asset management fees, and overhead associated with liquidation activities.

9. In principle, \( p_0 \) includes the cost of any regulation burden imposed by the insurer. In the case of implicitly priced deposit insurance, these costs set the magnitude of \( p_0 \). (See Buser, Chen and Kane (1981).) Our findings are robust across different values for \( p_0 \).

10. Since analytical solutions are not readily obtainable, all solutions here are derived by numerical methods. The approach taken is to perform a grid search across a wide range of parameter values and choose those values at which the sum of squared errors (SSE) is equal to zero (to within 8 decimal places). SSE is defined as

\[
SSE = [(p_0^{BS} - p_0)/p_0]^2 + [(k_0^{BS} - k_0)/k_0]^2
\]

where \( p_0^{BS} \) is the Black-Scholes value, per dollar of deposits, of the put option effectively written by the insurer, and \( k_0^{BS} \) is the Black-Scholes value, per dollar of deposits, of the call option effectively purchased by the shareholders.

11. These two effects on desired deposit spreads may be correlated, i.e., the asset characteristics, such as return structure, marketability and private information content, that we have
associated with audit costs per dollar of assets may tend to be greater for higher risk assets. Comments by an anonymous referee helped us clarify this point.

12. Karekan (1985) and others have proposed limiting deposit insurance to this sort of "narrow" bank, generally with the additional specification that the assets should be riskfree.

13. The former chairman of the Federal Deposit Insurance Corporation, Mr. L. W. Seidman, also recently commented on liquidation cost effects and maintained that “experience shows that when a bank is closed, the value of its assets usually drops 10 to 15 percent ... even if regulators were to close a bank when it has two percent capital instead of zero capital, the assets intended for long-term investment simply could not be liquidated at the values of a going concern”. See Seidman (1991).

14. Note, we use \( V_0 e^{rt} \) rather than \( V_0 \) for tractability reasons only. Also, note that when liquidation costs are modeled according to equation (3), the explicit expression for \( V \) is \( V = [(l_0 + l_1)/(1 + l_1)] V_0 e^{rt} \).

15. The qualitative nature of the results is not sensitive to whether \( l_1 \) is positive or zero, or whether \( l_1 \) is large or small, as long as \( l_0 \) is at least as large as \( l_1 \).

16. Our results are not sensitive to the specific values chosen for the liquidation and audit cost parameters.

17. See Gennotte and Pyle (1991) who model a situation in which bank asset values systematically differ from the purchase price of those assets.

18. Assuming that all relevant agents are risk neutral, the current value of any contingent claim on the bank’s asset value is the discounted expected future cash flows from that claim, discounted at the riskfree rate. Thus

\[
P_0 = e^{-rt} E[\max(0, D_1 - V_1)]
\]

\[
E_0 = e^{-rt} E[\max(0, V_1 - D_1)]
\]
where $E[.]$ is the expectations operator, and we assume that the value of the bank's assets follows a log normal process, i.e.,

$$V_T = V_0e^{\sigma - 0.5 \sigma^2 T + \sigma z T}$$

where $z$ is a standard normal random variable. $\sigma$ is the expected return on the bank's loan portfolio which we denote here as $r_L$.

19. When there are no liquidation costs and only audit costs, the loan spread is higher at higher risk levels. This is because total audit costs are higher at higher risk levels, and here the audit costs are being passed on to borrowers.

20. Recall that these results depend on a risk neutrality assumption. If loan rate spreads involved a premium due to risk, this factor would increase with higher levels of risk.

21. It is important that the diversification is real and not superficial. Loans collateralized by real estate did not provide much diversification for savings and loan associations.

22. In the analysis to this point, we have implicitly assumed that the bank invests in one type of asset, and that the value of this asset is log normally distributed. When we move to considering two types of assets, care must be taken with aggregation. The sum of two log normal random variables is not a log normal random variable. We assume that the bank follows a dynamic investment strategy so that the proportion of the bank's portfolio invested in each of the two assets remains constant through time. Under this assumption, the value of the bank's overall portfolio will continue to follow a log normal process.

APPENDIX

Present value of a security that pays $C$ dollars when $V_t \leq D_1$, and zero otherwise:

According to the Black and Scholes' (1973) world of arbitrage-free pricing,

$$B_0 = e^{-r_1} C \text{ pr}[\tilde{V}_1 < D_1]$$

where $\text{pr}[\tilde{V}_1 < D_1]$ is the probability that $\tilde{V}_1$ is less than $D_1$. $\tilde{V}_T$ is assumed to follow a log normal process such that

$$dV = \alpha V dt + \sigma V dz.$$ 

Thus,

$$\tilde{V}_1 = V_0 e^{(\alpha - 0.5\sigma^2 + \sigma \tilde{z})}$$

where $\tilde{z}$ is a standard normal random variable. Then

$$\text{pr}[\tilde{V}_1 < D_1] = \text{pr} \left[ \tilde{z} < \frac{\sigma}{2} - \left( \frac{\alpha + \ln(V_0/D_1)}{\sigma} \right) \right]$$

In this expression $\alpha$ can be replaced by $r_f$, the riskfree rate. Thus,

$$\text{pr}[\tilde{V}_1 < D_1] = \text{pr} \left[ \tilde{z} < \frac{\sigma}{2} - \left( \frac{r_f + \ln(V_0/D_1)}{\sigma} \right) \right] = N(-y + \sigma \nu)$$

where (as defined in the text)

$$y = \ln(1 + k_0 - p_0) + \frac{\mu_D}{\sigma \nu} + \frac{\sigma}{2}$$

Thus,

$$B_0 = e^{-r_1} C N(-y + \sigma \nu).$$
REFERENCES


TABLE 1: Fair Risk-Based Capital Ratios and Deposit Rate Spread

Table 1a: Zero Audit Cost Case

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<tr>
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</table>

Table 1b: Non-Zero Audit Cost Case

\[
\begin{array}{cccccccc}
 a = 0.0005 & a = 0.0010 & a = 0.0015 \\
 k_0^* & \mu_D^* & k_0^* & \mu_D^* & k_0^* & \mu_D^* & \sigma_V \\
 0.00743 & 0.00050 & 0.00891 & 0.00101 & 0.01115 & 0.00151 & 0.01 \\
 0.02141 & 0.00051 & 0.02434 & 0.00102 & 0.02889 & 0.00154 & 0.02 \\
 0.03781 & 0.00052 & 0.04244 & 0.00104 & 0.04952 & 0.00157 & 0.03 \\
 0.05615 & 0.00053 & 0.06250 & 0.00106 & 0.07242 & 0.00161 & 0.04 \\
 0.07604 & 0.00054 & 0.08422 & 0.00108 & 0.09741 & 0.00164 & 0.05 \\
 0.09725 & 0.00055 & 0.10747 & 0.00111 & 0.12449 & 0.00168 & 0.06 \\
 0.11975 & 0.00056 & 0.13221 & 0.00113 & 0.15375 & 0.00173 & 0.07 \\
 0.14347 & 0.00057 & 0.15839 & 0.00116 & 0.18544 & 0.00178 & 0.08 \\
 0.16839 & 0.00058 & 0.18606 & 0.00119 & 0.21991 & 0.00183 & 0.09 \\
 0.19450 & 0.00059 & 0.21526 & 0.00121 & 0.25776 & 0.00189 & 0.10 \\
\end{array}
\]

$p_0 = \text{deposit insurance premium per dollar of deposits, assumed here to be 0.0023;}

a = \text{audit costs per dollar value of the bank's assets;}

$\sigma_V = \text{standard deviation of the return on bank's assets.}$

$k_0^* = \text{the fair capital-to-deposit ratio; } \mu_D^* = \text{the equilibrium spread between the riskfree rate}
\text{and the deposit rate; these are the solutions to the model characterized by conditions (1a)}
\text{and (2a) in the text.}$

Note, liquidation costs are assumed to be zero for both tables 1a and 1b.
Total Insurer's Liability in the presence on Liquidation Costs (LC)

\[ LC = \begin{cases} 
  l_0 V_0 e^{\text{lf}} + l_1 (V_0 e^{\text{lf}} - V) & \text{if } V < V_1 \leq D_1 \\
  0 & \text{otherwise}
\end{cases} \]

This liability [Figure 1 (a)] is equivalent to:
- Liability from basic deposit insurance coverage [Figure 1 (b)]
- Extra liability due to liquidation costs [Figure 1 (c)]
- Savings from abandoning worthless assets [Figure 1 (d)]

Note: \( L = (l_0 + l_1) V_0 e^{\text{lf}} \)

One put with exercise price \( D_1 \)

\( l_1 \) puts with exercise price \( D_1 + \) security with payout \( (L - l_1 D_1) \) when \( V_1 \leq D_1 \) only

\((1 + l_1)\) puts with exercise price \( V \)
Figure 2: Equilibrium Capital-to-Deposits Ratios

Plot shows the equilibrium capital-to-deposit ratio as a function of the standard deviation of the return on the bank's assets. The deposit insurance premium per dollar of deposits is assumed to be 0.0023. Total liquidation costs are of the form \( LC = l_0 V_0 e^{r_1} + l_1 (V_0 e^{r_1} - V_1) \), and audit costs are assumed to equal \((0.0005 + 0.01 l_0) V_0\). The capital-to-deposit ratios \( R1 \), \( R2 \) and \( R3 \) correspond to values for \((l_0, l_1)\) of \((0.00, 0.00)\), \((0.05, 0.01)\) and \((0.10, 0.02)\), respectively.
Plot shows the equilibrium spread between the riskfree rate and the promised rate to depositors as a function of the standard deviation of the return on the bank’s assets. The deposit insurance premium per dollar of deposits is assumed to be 0.0023. Total liquidation costs are of the form $LC = l_0 V_0 e^{r_f} + l_1 (V_0 e^{r_f} - V_1)$, and audit costs are assumed to equal $(0.0005 + 0.01 l_0) V_0$. The deposit rate spreads $S1$, $S2$ and $S3$ correspond to values for $(l_0, l_1)$ of (0.00, 0.00), (0.05, 0.01) and (0.10, 0.02), respectively.
Figure 3b: Equilibrium Loan Rate Spreads

The plot shows the equilibrium spread between the expected return on the loan portfolio and the riskfree rate as a function of the standard deviation of the return on the bank's assets. The deposit insurance premium per dollar of deposits is assumed to be 0.0023. Total liquidation costs are of the form $LC = l_0 V_0 e^{r_f} + l_1 (V_0 e^{r_f} - V_1)$, and audit costs are assumed to equal $(0.0005 + 0.01 l_0) V_0$. The spread between the riskfree rate and the promised rate to depositors is assumed to equal the minimum audit cost rate. The loan rate spreads $S_1$, $S_2$ and $S_3$ correspond to values for $(l_0, l_1)$ of $(0.00, 0.00)$, $(0.05, 0.01)$ and $(0.10, 0.02)$, respectively.
Plot shows relation between the equilibrium loan rate spread and the fair capital/premium combination when the standard deviation of the return on the bank’s assets is 0.04. On the horizontal axis are the values for the fair capital-to-deposit ratio \(k_0^*\). As the fair capital-to-deposit ratio increases in value, the insurance premium per dollar of deposits \(p_0^*\) declines in value in such a way that the capital/premium combination guarantees that the premium paid is equal to the insurer’s liability. (See table that follows.) Total liquidation costs are assumed to equal \(l_0V_0e^{r_f} + l_1(V_0e^{r_f} - V_1)\). Audit costs equal \((0.0005 + 0.01l_0)V_0\). The spread between the riskfree rate and the promised rate to depositors is assumed to equal
the minimum audit cost rate. The loan rate spreads $S_1$, $S_2$ and $S_3$ correspond to values for $(l_0, l_1)$ of $(0.00, 0.00)$, $(0.05, 0.01)$ and $(0.10, 0.02)$, respectively. The values for $p_0^*$ in (a), (b) and (c) in the table that follows also correspond to the cases where $(l_0, l_1)$ take values of $(0.00, 0.00)$, $(0.05, 0.01)$ and $(0.10, 0.02)$, respectively.

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The bank is assumed to invest in a portfolio of two assets. Plot shows the capital-to-deposit ratio as a function of the proportion \((\text{alpha})\) invested in asset 1, for different levels of the correlation coefficient \((\rho)\) between the returns on the two assets. Here, \(\sigma_1 = 0.055, \sigma_2 = 0.045\), where \(\sigma_i\) is the standard deviation of the return on asset \(i\). Liquidation costs are zero. The deposit insurance premium per dollar of deposits is assumed to be 0.0023. Audit costs per dollar of assets are set at 0.0005. The spread between the riskfree rate and the promised rate to depositors is set equal to the audit cost rate. \(AB\) depicts the linear capital rule when only asset variances are taken into account, ignoring diversification effects and liquidation costs.
The bank is assumed to invest in a portfolio of two assets. Plot shows the capital-to-deposit ratio as a function of the proportion \((\alpha)\) invested in asset 1, for different levels of the correlation coefficient \((\rho)\) between the returns on the two assets. Here, \(\sigma_1 = 0.055, \sigma_2 = 0.045\), where \(\sigma_i\) is the standard deviation of the return on asset \(i\). Liquidation costs equal \(l_0V_0 e^{r\tau} + l_1(V_0 e^{r\tau} - V_1)\), and apply only to asset 1. Audit costs equal \((0.0005 + 0.01I_0)V_0\). The deposit insurance premium per dollar of deposits is assumed to be 0.0023. The spread between the riskfree rate and the promised rate to depositors is assumed to equal the minimum audit cost rate, 0.0005. \(AB\) depicts the linear capital rule when only asset variances are taken into account, ignoring diversification effects and liquidation costs. \(AC\) depicts the case where asset variances and liquidation costs are taken into account, but not diversification effects.