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Risk in Banking and Capital Regulation

DAESIK KIM and ANTHONY M. SANTOMERO*

ABSTRACT

This paper investigates the role of bank capital regulation in risk control. It is known that banks choose portfolios of higher risk because of inefficiently priced deposit insurance. Bank capital regulation is a way to redress this bias toward risk. Utilizing the mean-variance model, the following results are shown: (a) the use of simple capital ratios in regulation is an ineffective means to bound the insolvency risk of banks; (b) as a solution to problems of the capital ratio regulation, the “theoretically correct” risk weights under the risk-based capital plan are explicitly derived; and (c) the “theoretically correct” risk weights are restrictions on asset composition, which alters the optimal portfolio choice of banking firms.

THE RECENT INCREASE in bank failures, especially after the 1980 and 1982 Deregulatory Acts, has again ignited a controversy over the risk portfolio of the banking industry. Given the importance of this sector, there has been increased scrutiny of the industry’s motives for risk taking and possible regulatory changes to improve its stability. These investigations have centered around two rather complementary areas.

The first of these is the role of deposit insurance and how its current pricing procedure encourages risk taking and justifies current bank regulations. The works of Buser, Chen, and Kane [4], Kane [9], and Benston et al. [2] have made substantive contributions. The authors demonstrates the way in which our current fixed-rate insurance system rewards risk taking by the firm and insulates it through deposit insurance from the market discipline that needs to exist to ensure proper risk evaluation.

This realization has led these authors to propose a series of regulatory changes to encourage proper portfolio choice within the industry. These include a shift to market value accounting, risk-based deposit insurance premiums, and additional capital regulation. The last of these serves as a method of coinsurance whereby higher capital levels require the bank to absorb greater losses in the event of failure and encourage additional prudence in management. In essence it is one method of risk reduction that may offset the risk preference imposed on the industry due to the inappropriate insurance pricing. Because the amount of capital influences the probability of bank insolvency and thus the soundness of the entire banking system, the regulators, *ceteris paribus*, prefer more capital to less.¹

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¹ See Santomero [17] for a summary of the conflicting views on the bank capital issue.

However, stringent capital regulation via a simple capital to asset ratio gives banks an incentive to increase their business risk by portfolio realignment. This is especially so under the regulation that does not consider asset quality in determining capital requirements. Thus, some banks could circumvent the intent of regulation. As Koehn and Santomero [10] pointed out, it appears possible that regulatory efforts to control risk taking through capital ratio regulation may actually increase the probability of failure for some institutions.

Bank circumvention of the capital ratio requirement has concerned bank regulators and has led to a new proposal, known as the “risk-related” capital plan. This attempts to factor explicitly the quality of assets and off-balance-sheet risk exposure into the calculation of a bank’s required capital. The regulators intend to evaluate an individual bank’s unique risk profile in determining its capital adequacy, by imposing risk weights that specify the minimum capitalization rates on assets. Banks engaged in less secure banking practices, including off-balance-sheet activities, would be required to keep more capital.

The purpose of this paper is to evaluate the effectiveness of capital regulation in an industry that is characterized by fixed-rate deposit insurance pricing and implicit, if not explicit, deposit guarantees. It considers both the uniform capital ratio requirement and the new risk-related capital plan in controlling bank risk and maintaining a “safe and sound” banking system. Since previous research (e.g., Mingo and Wolkowitz [13], Kahane [8], and Koehn and Santomero [10]) has addressed only the problems of, without suggesting any solution to, the capital ratio regulation, one more specific goal of this paper is to derive the “theoretically correct” risk weights as a solution to those cited problems.

Section I establishes the basic framework used in analyzing bank capital adequacy. The model builds upon the portfolio approach utilized by Koehn and Santomero [10]. It presents the capital regulations as a means of restricting bank opportunity sets and shows why the ratio regulation fails to reduce risk taking that is inherent in our present regulatory and insurance structure. Section II examines the newly proposed risk-related capital plan and its ability to redress the risk preference behavior of banks. Section III contains a summary and conclusion.

I. The Model

A. *The Assumptions*

To develop a mean-variance model for banking firms, the following assumptions are made and the relevance of such assumptions discussed.

- (A1) Banks are price takers in their respective markets.
- (A2) A bank holds n assets and one deposit item the returns of which have a joint normal distribution. The i th asset has expected return u_i and variance σ_i^2 . The deposit has expected cost u_0 and variance σ_0^2 .
- (A3) Banks are single-period risk-averse expected utility maximizers.² The utility function is approximated by the first and second moments of the

² For a literature survey on bank objective functions, see Santomero [18].

final wealth. Thus, the bank's strictly quasi-concave objective function U is defined over mean, E , and standard deviation, σ , of return on equity capital.³ The risk preference is measured by the Pratt [15] relative risk aversion parameter Γ .

- (A4) Bank regulators are interested in a "safe and sound" banking system and hence try to bound the probability of bank insolvency by α through capital adequacy requirements.⁴

An attempt to apply the above assumptions to banking firms needs some discussion of their unique features. The first comes from the regulatory constraints on bank operations, as Hart and Jaffee [6] have pointed out. Among them, the restrictions on bank product market (Glass-Steagall Act and Bank Holding Company Acts) and geographic market (McFadden Act) deserve a discussion. The product market restrictions limit banks to only a subset of existing assets. Their general effect will be the shrinkage of the bank opportunity set (Levy [11], Blair and Heggstad [3]). In addition, to the extent that the current branching laws limit the ability of banks to diversify geographically over the allowable assets, banks operate in segmented markets and face potentially different opportunity sets. This implies a further shrinkage of an individual bank's opportunity set to a (different) portion of the "Glass-Steagall Act/Bank Holding Company Acts defined" set. Thus, (A1) implies that banks are price takers in their own restricted set of markets.

The assumption of given expected returns and variances is introduced to simplify matters, which may not be true for banking firms at least in some markets such as loans. While a downward-sloping loan demand function can be introduced (James [7]), this would unduly complicate the analysis without adding any important insights. On the other side of the balance sheet, the sources of bank non-equity funds are composed of core deposits and purchased funds. Unfortunately, it is hard to incorporate the stochastic quantity flows of core deposits into a mean-variance model. One way to get around the problem is to assume that, when unexpected core deposit outflows happen, banks can issue manageable liabilities the rates of which are uncertain and determined by the market, in order to maintain a given size of the asset portfolio. Such liability management ability of banks makes the cost of deposits stochastic while there is no quantity risk. However, due to the limit on the insured amount of deposits, the cost of large deposits may depend on the leverage ratio itself as well as asset

³ When K is the initial wealth, R is the random return on equity capital, and V is the utility function, the objective function $U(E, \sigma)$ can be derived using the Taylor expansion:

$$\begin{aligned} E[V(K + R \cdot K)] &= E[V(K) + V'(K) \cdot (R \cdot K) + \frac{1}{2} \cdot V''(K) \cdot (R \cdot K)^2 + O^3] \\ &= V(K) + V'(K) \cdot K \cdot [E(R) - \frac{1}{2} \cdot \Gamma \cdot \{E(R)^2 + \sigma^2\}] \\ &= U[E(R), \sigma], \end{aligned}$$

where E is the expectation operator and $\Gamma = -K \cdot [V''(K)/V'(K)]$.

⁴ As noted by the referee, bounding the risk of bank solvency is not the same as controlling the solvency of the insurance fund or assuming that it is actuarially sound. On this latter subject, see Benston et al. [2] or Goodman and Santomero [5].

returns. The current assumption of functional independence between firm decisions and deposit costs assumes that depositors, large or small, view themselves as having de facto insurance. Under the simplified competitive asset and deposit market assumption, the bank's portfolio problem involves the determination of the proportions of each balance sheet item relative to the equity capital.

B. The Efficient Frontier and Portfolio Choice

To see the impact of capital regulation on the bank's opportunity set, this subsection first examines the efficient frontier for a given leverage ratio. A given equity-to-asset ratio k implies a fixed deposit-to-equity ratio $(1 - 1/k)$. The bank solves the following problem to ascertain the efficient frontier:

$$\min_{\underline{X}_1} \frac{1}{2} \sigma_k^2 = \frac{1}{2} \underline{X}' \underline{V} \underline{X} = [1 - 1/k, \underline{X}'_1] \begin{bmatrix} \sigma_0^2 & \underline{V}'_1 \\ \underline{V}_1 & \underline{V}_2 \end{bmatrix} \begin{bmatrix} 1 - 1/k \\ \underline{X}_1 \end{bmatrix}, \quad (1)$$

subject to

$$E_k = (1 - 1/k)u_0 + \underline{X}'_1 \underline{U}_1,$$

$$1/k = \underline{X}'_1 \underline{e},$$

$$\underline{X}_1 > 0 \quad \text{and} \quad 0 < k \leq 1,$$

where

- (i) u_0 and σ_0^2 are the mean and variance of costs of deposits.
- (ii) \underline{U}_1 is an $n \times 1$ vector of asset returns $[u_i]$ for $i = 1, \dots, n$.
- (iii) \underline{V}_1 is an $n \times 1$ vector of covariance $[\sigma_{0i}]$ between deposit cost and asset returns. \underline{V}_2 is an $n \times n$ variance-covariance matrix of asset returns $[\sigma_{ij}]$ for $i, j = 1, \dots, n$ and is positive-definite.
- (iv) \underline{X}_1 is an $n \times 1$ vector of x_i that is the i th asset holding, as a proportion of the equity capital, and $\underline{X}_1 \geq \underline{0}$ due to short sale restrictions.
- (v) \underline{e} is an $n \times 1$ vector with first $(n - 1)$ elements of 1 and n th element of 0. Therefore, $\underline{X}'_1 \underline{e} = 1/k$.
- (vi) E_k and σ_k are the expected value and the standard deviation of return per unit of equity capital.

The solution to this minimization problem determines the efficient portfolio frontier in (E, σ) space and portfolio weights \underline{X}'_1 at each efficient portfolio.

An examination of solutions to equation (1) (see Appendix) indicates that, as k increases (less leveraged), the resulting efficient frontier moves down to the left in (E, σ) space and that a more leveraged frontier moves down to the left in (E, σ) space and that a more leveraged frontier cuts from below another less leveraged one. When full flexibility of k is allowed in equation (1), the global frontier will coincide with the Merton [12] hyperbola and is an envelope of efficient frontiers with all levels of k . These regulations are shown in Figure 1. As the equity-to-asset ratio increases from k^* to k^R , the efficient frontier moves down from $P_0P_1P_2$ to $R_0G_1R_2$. Each frontier touches the global frontier $G_0G_1G_2$ from below at P_1 and G_1 , respectively. As we move up along the global frontier,

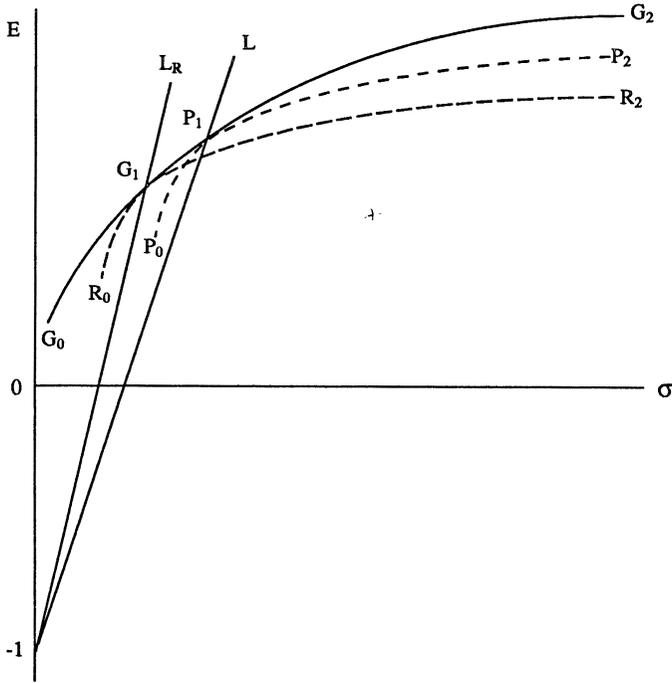


Figure 1. The effect of capital regulation on the probability of insolvency. $G_0G_1G_2$ is the global frontier. $R_0G_1R_2$ is the efficient frontier conditional on capital ratio k^R . L_R is the set of portfolios, including $G_1:(E^R, \sigma^R)$, with the probability of insolvency equal to $\alpha > 0$. L is the set of portfolios, including $P_1:(E^*, \sigma^*)$, with the probability of insolvency equal to $\beta > \alpha$.

the underlying portfolio corresponds to a higher expected return on equity E and a lower k and, hence, a riskier portfolio.

The actual portfolio choice of banks from the identified opportunity set will depend on their utility function. The strictly quasi-concave objective function $U(E, \sigma)$ guarantees a unique solution to the bank's portfolio choice problem. The solution is determined by equating the bank's marginal rate of substitution (MRS) between return and risk,⁵ $-U_E/U_\sigma = \Gamma \cdot \sigma/(1 - \Gamma \cdot E)$, to the marginal rate of transformation (MRT) along the derived efficient frontier. A set of $[E(\Gamma), \sigma(\Gamma), k(\Gamma), \underline{X}_1(\Gamma)]$ characterizes the optimal solution and depends on the bank's risk aversion parameter Γ . In the absence of capital regulation, the global frontier becomes feasible to a bank. Let's assume that the resultant portfolio of a bank with the risk aversion parameter Γ is $P_1 : [E^*(\Gamma), \sigma^*(\Gamma), k^*(\Gamma)]$ in Figure 1. This portfolio will be used as a reference portfolio for the discussion of capital regulation in the following section.

⁵ From footnote 3,

$$MRS = \frac{U_{E(R)}}{U_\sigma} = - \frac{\partial E[V(\cdot)]/\partial \sigma}{\partial E[V(\cdot)]/\partial E(R)} = \frac{\sigma}{(1/\Gamma) - E(R)}$$

C. Probability of Insolvency and Capital Ratio Regulation

Bank insolvency is defined as an event where the bank's equity capital is completely eliminated, i.e., $E \leq -1$. While in reality book values matter to regulators and forbearance may forestall closings, for the current analysis it appears appropriate to use a market value determination of insolvency.

When the return on equity is normally distributed, the probability of insolvency, denoted by p , can be specified for any (E, σ) and will satisfy

$$\text{prob}[E \leq -1] = \text{prob} \left[\frac{E - E}{\sigma} \leq \frac{-1 - E}{\sigma} \right] = p. \quad (2)$$

Thus,

$$E = -1 - \Phi(p) \cdot \sigma \quad \text{and} \quad -\Phi(p) = \frac{E + 1}{\sigma}, \quad (3)$$

where $\Phi(\cdot)$ is the inverse of the cumulative standard normal distribution function. The value of $\Phi(\cdot)$ is always negative since the probability of failure considers only the lower end of the distribution. A larger absolute value of $\Phi(\cdot)$ corresponds to a lower insolvency risk for a chosen portfolio.⁶ For example, the insolvency risk of portfolio P_1 , (E^*, σ^*) , is the β that satisfies $-\Phi(\beta) = (E^* + 1)/\sigma^*$.

Equation (3) also provides a convenient tool for graphically comparing the risks of different portfolios. It represents the line connecting $E = -1$ and a chosen portfolio, (E, σ) , with a slope of $-\Phi(p) = (E + 1)/\sigma$. Thus, if one portfolio forms a steeper line than another, the former has a lower insolvency risk than the latter. In Figure 1, any portfolios lying to the left of the line L : $E = -1 - \Phi(\beta) \cdot \sigma = -1 - [(E^* + 1)/\sigma^*] \cdot \sigma$ have a steeper slope than P_1 and, thus, lower insolvency risk than β . Accordingly, portfolios lying to the right of the line L have higher insolvency risk than β . The probability of insolvency is constant at β along the line L .

Consider now where the regulators wish to set a solvency standard. They want to control the likelihood of bank insolvency by setting the upper bound on $\text{prob}[E \leq -1]$ by α . The level of α is most likely determined by considering the tradeoff between the regulators' safety goal and preservation of economic efficiency as well as α 's consistency with the mispriced deposit insurance. With a normality assumption, the solvency standard $\text{prob}[E \leq -1] \leq \alpha$ is converted to

$$E \geq -1 - \Phi(\alpha) \cdot \sigma. \quad (4)$$

In a sense, equation (4) represents the regulator's preference, which depends on the probability of bank insolvency and is, in fact, Roy's [16] safety-first or "minimum α " utility function. In Figure 1, only the portfolios to the left of L_R : $E = -1 - \Phi(\alpha) \cdot \sigma = -1 - [(E^R + 1)/\sigma^R] \cdot \sigma$ are acceptable according to the regulator's solvency standard and are classified as safe (sound) banks. The portfolio P_1 , however, does not meet the standard since the line L has a flatter

⁶ For example, when the probability of bankruptcy is 2.5%, $\Phi(p = 0.025)$ will be -1.96 while $\Phi(p = 0.001) = -3.1$.

⁷ See Morgan [14] and Benston et al. [2].

slope than the regulators' reference line, L_R . ($-\Phi(\alpha)$ is smaller than $-\Phi(\beta)$.) This bank will therefore be classified as risky.

To achieve the solvency standard, the regulators currently enforce the capital ratio requirement. Since the frontier with the capital ratio of k^R , $R_0G_1R_2$, touches the global frontier $G_0G_1G_2$ at G_1 , (E^R, σ^R) , the regulators force banks to operate with an equity-to-asset ratio of at least k^R . By doing so, they hope that, when $k \geq k^R$ is binding, a bank will chose G_1 instead of those portfolios on G_1G_2 such as P_1 . However, a risky bank may not move to G_1 in its attempt to satisfy $k \geq k^R$. It is true that constraints on the capital ratio lead to a shrinkage of the feasible set. In Figure 1, the requirement $k \geq k^R$ makes the area between G_1G_2 and G_1R_2 infeasible. However, the new constrained efficient frontier is not confined only to G_0G_1 , which the regulators wish to obtain through the ratio regulation. It still leaves portfolios on G_1R_2 feasible. When a bank chooses a portfolio on G_1R_2 , it satisfies the capital ratio requirement but not the solvency standard. In fact, any bank with a relative risk aversion parameter smaller than the critical value Γ^c with which a bank's MRS is equal to MRT at the portfolio G_1 ⁸ would choose a portfolio along G_1R_2 . Such banks reshuffle assets toward riskier ones (increase business risk) to offset the impact of forced lower leverage (lower financial risk)⁹ such that regulators fail to bound the insolvency risk by α .

In spite of the elimination of a portion of the bank's opportunity set by leverage restrictions, the dependence of the portfolio choice on the individual (risky) bank's preference impairs the effectiveness of the regulators' efforts to reduce insolvency risk through capital ratio regulation. In addition, to the extent that each bank may face a different opportunity set (thus, a different risk profile) due to, for example, the current branching laws or a specific liability structure, a uniform capital ratio regulation can hardly be an effective way to bound the insolvency risk in line with the flat insurance premium structure.

II. The Risk-Related Capital Plan

Failure of the uniform capital ratio regulation in bounding bank bankruptcy risk has led to the "risk-related" capital plan. According to the recent proposals,¹⁰ the new plan will (a) place bank assets into several risk categories and (b) assign a risk weight to each category to determine the minimum equity capital that should be maintained against it. The new plan tries to consider explicitly the different risk characteristics of individual assets and suggests that minimum required levels of bank equity capital depend on the riskiness of asset portfolios. In addition, the definition of assets includes off-balance-sheet items that have not been previously considered in evaluating the minimum required level of equity capital.

⁸ From the MRS in footnote 5 and the MRT along the frontier derived in the Appendix, Γ evaluated G_1 , (E^R, σ^R) , is

$$\Gamma^c = \frac{1}{E^R + [(D/W) \cdot (\sigma^{R2} - \sigma_{k.m}^2)]^{1/2}}.$$

⁹ See Kahane [8] and Koehn and Santomero [10].

¹⁰ See Bank for International Settlements [1].

The goal of the risk-related capital plan is to require banks to use more capital to finance risky projects and to support off-balance-sheet activities. The new schedule is thus specifically designed to counteract the risky banks' asset reshuffling caused by the "stringent" ratio regulation. The new schedule can be viewed as an attempt to reduce the implicit increase in deposit insurance exposure associated with the risky banks' asset portfolio choice, which is at least implicitly supported by the deposit guarantee and its fixed-rate pricing.

Abstracting from the operational details but maintaining the spirit of the new proposal, the theoretical form of the risk-related capital plan can be presented. Under the current model setup, the new guidelines imply that

$$q' \underline{X}_1 \leq 1, \quad (5)$$

where q is the $n \times 1$ regulator's imposed risk weight vector. The level of equity capital on hand should be larger than the sum of the minimum equity required to support each asset, including off-balance-sheet activities, in a portfolio.

The current task is to determine the "theoretically correct" risk weights, defined below as $q^* = [a_i^*]$ for $i = 1, 2, \dots, n-1, n$. a_i^* is the "minimum" amount of equity capital that a bank should hold to back one unit of the i th asset under the new plan such that the plan can achieve the solvency goal, bounding the probability of bank insolvency by α .

A. The Necessary and Sufficient Condition

The regulators want to make sure that banks operate in the region to the left of the line $L_R: E = -1 - \Phi(\alpha) \cdot \sigma$ in Figure 2. The regulators' goal can be achieved when they design a set of weights, q^* , such that the voluntarily chosen portfolio of a risky bank under the new constraint, equation (5), satisfies the solvency standard, equation (4). To be effective, the new plan should work regardless of the risk aversion parameters of banks.

The new plan with theoretically correct risk weights must eliminate the area between G_1G_2 and G_1G_3 in order to be successful in bounding insolvency risk by α independently of the individual banks' risk preferences. Since the portfolios between G_1G_2 and G_1G_3 are feasible under no regulation, the risky banks with $\Gamma < \Gamma^c$ could move up along G_1G_2 . The capital ration regulation $k \geq k^R$ succeeds in eliminating the area between G_1G_2 and G_1R_2 but not the area between G_1R_2 and G_1G_3 . If the new constraint succeeded in eliminating the target area between G_1G_2 and G_1G_3 , any risky bank trying to choose a portfolio with $E > E^R$ would be forced to choose the portfolio $G_1, (E^R, \sigma^R)$, simply because there are no other feasible portfolios with $E > E^R$. Even after the elimination of the area between G_1G_2 and G_1G_3 , any safe bank with $\Gamma \geq \Gamma^c$ would not be affected by the new proposal. Thus, equation (5) with the correct weights becomes redundant to the safe bank's problem while it is binding to risky banks.

Therefore, the necessary and sufficient condition for the success of bank risk management through capital regulation is to eliminate the area between G_1G_2 and G_1G_3 from the opportunity set. The imposition of the risk weights under the new plan should accomplish this task. Alternatively, the risk weights should be designed such that the highest expected return on the equity capital of banking firms is bounded by E^R . As can be seen in Figure 2, E^R is the expected return on

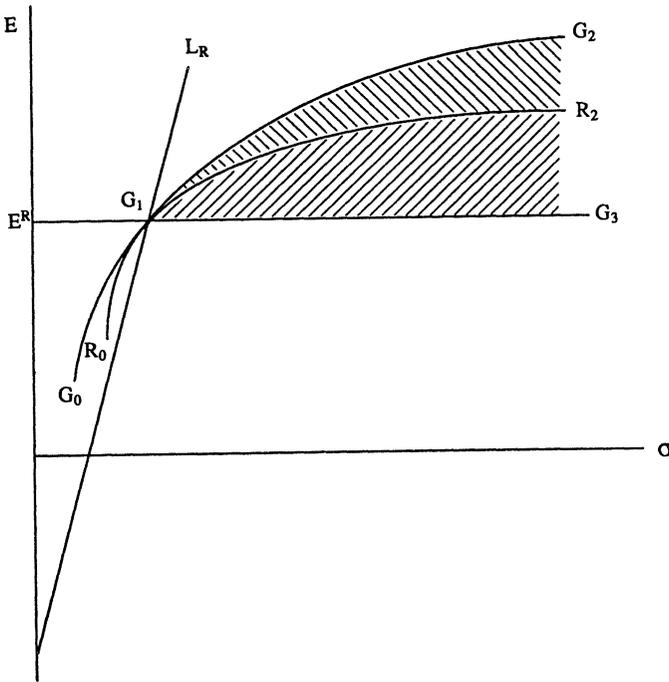


Figure 2. The necessary and sufficient condition to bound insolvency risk. $G_0G_1G_2$ is the global frontier. $R_0G_1R_2$ is the efficient frontier conditional on capital ratio k^R . E^RG_3 is the upward bound on expected return associated with the solvency constraint.

equity at G_1 , where the regulators' preference line L_R and the bank's global efficient frontier $G_0G_1G_2$ intersect, and is determined independently of the individual banks' preference.

B. The Derivation of Risk Weights

The condition that the expected return on equity should be bounded by E^R enables the regulators to concern themselves only with the expected return on bank equity. The regulators' goal of imposing the new constraint is reduced to finding risk weights such that the imposition of equation (5) should lead to a restriction on a bank's attainable expected return on equity E ; i.e.,

$$E^R \geq E = (1 - \sum_{i=1}^n x_i) \cdot u_0 + \sum_{i=1}^n x_i \cdot u_i, \tag{6}$$

where E^R = the expected return on the portfolio G_1 or the highest expected return on equity capital among those satisfying the ruin constraint, equation (4).

The approach adopted here is to get the optimal risk weights a_i^* from the linearity of equation (6). Specifically we derive the risk weights that do not allow the possibility that a bank can exploit a specific asset in order to increase the expected return on equity above E^R . When the contribution of the i th asset, after deposit costs, to the expected return on equity capital is bounded by E^R , a bank cannot use solely the i th asset to increase E above E^R . When every asset's contribution to E is limited by E^R , no linear combination of such assets can

produce the expected return on equity higher than E^R . Thus, the imposition of risk weights should equilibrate the net returns of different assets evaluated per unit of equity when the new constraint is binding.

When the risk weights q are imposed by the regulators, a bank should hold a least a_i units of equity capital, also implying that it can use at maximum $(1 - a_i)$ units of deposits, in order to include one unit of the i th asset in the portfolio. At the same time, the expected return on equity capital used to support one unit of the i th asset should be bounded by E^R . Therefore, the risk weights a_i should be set to satisfy, for $i = 1, 2, \dots, n - 1, n$,

$$u_i \leq (1 - a_i) \cdot u_0 + a_i \cdot E^R = u_0 + a_i \cdot (E^R - u_0). \tag{7}$$

Equation (7) indicates that a_i should be set so that the return on the i th asset covers the deposit funding cost, $(1 - a_i) \cdot u_0$, and the return on equity funds, not higher than E^R per unit of equity invested, $a_i \cdot E^R$.

Solving for a_i in equation (7) leads to, for all assets i ,

$$\begin{aligned} a_i &\geq \frac{u_i - u_0}{E^R - u_0} && \text{if } u_i - u_0 > 0, \\ a_i &= 0 && \text{if } u_i - u_0 \leq 0. \end{aligned} \tag{8}$$

Under these weights, the expected return on equity E cannot exceed E^R by solely exploiting a single asset or a combination of several assets. The case $u_i \geq u_0$ implies that such assets yield a negative (or zero) expected return on equity after considering funding costs u_0 . A risky bank would never use these assets for an increase in the expected return on equity although it may hold them for diversification purposes. Only assets with the expected return higher than u_0 need to be considered so that their net contributions to E do not exceed E^R .

Since the sufficient condition for bounding E by E^R and thus the insolvency risk by α requires equation (8), the regulators should set the “minimum” capitalization rate of the i th asset equal to the right-hand side of equation (8). Therefore, the “theoretically correct” risk weights a_i^* should be, for all i ,

$$\begin{aligned} a_i^* &= \frac{u_i - u_0}{E^R - u_0} && \text{if } u_i - u_0 > 0, \\ a_i^* &= 0 && \text{if } u_i - u_0 \leq 0. \end{aligned} \tag{9}$$

Equation (9) shows that the only needed information for the determination of risk weights is (a) the expected returns on assets and deposit costs $\underline{U} = [u_i]$, (b) the variance-covariance structure $\underline{V} = [\sigma_{ij}]$, and (c) the regulators’ upper bound on bank insolvency risk α . However, the correct risk weights are *independent* of the individual banks’ preferences. (a) and (b) determine the shape and position of the efficient frontier a specific bank faces, and (c) determines the reference portfolio G_1 in Figure 2 and thus the maximum allowable expected return on equity capital E^R as a function of $(\underline{U}, \underline{V}, \alpha)$.¹¹ With knowledge of these three

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$$E^R = \frac{(\underline{U}' \underline{V}^- \underline{e}) \cdot \Phi(\alpha)^2 + Z + \Phi(\alpha) \cdot [Z \cdot \{2 \cdot (\underline{U}' \underline{V}^- \underline{e}) + (\underline{e}' \underline{V}^- \underline{e}) + (\underline{U}' \underline{V}^- \underline{U}) - \Phi(\alpha)^2\}]^{1/2}}{(\underline{e}' \underline{V}^- \underline{e}) \cdot \Phi(\alpha)^2 - Z}$$

factors, one can determine the correct risk weights unique to any bank(s), regardless of its preference structure.

Only with the restriction on the expected return would risky banks always choose portfolio G_1 in Figure 2, which is the minimum-variance portfolio with the expected return E^R . When the new constraint is binding, a risky bank wishing to deviate from G_1 by reshuffling the portfolio toward riskier assets may be able to increase the gross return on assets but ends up with the same expected return on equity. The new constraint requires corresponding increase in equity base. This situation represents a shift from G_1 to a portfolio on G_1G_3 . Therefore, as long as banks are rational in the first-order-stochastic-dominance sense, those risky banks with lower risk aversion parameters are forced back to G_1 and will have the same insolvency risk of α . For banks that already choose portfolios on G_0G_1 even under no regulation, the new constraint and resultant partial elimination of opportunity set are redundant.¹² The imposition of the risk weights in equation (9) guarantees the successful achievement of the regulators' safety goal, regardless of banks' preference structures.

Simple properties of optimal risk weights can be examined. First, it can easily be shown that, for a given bank opportunity set,

$$a_i^* > a_j^* \quad \text{if} \quad u_i > u_j > u_0. \quad (10)$$

When the i th asset has a higher expected return than the j th asset, the risk weight on the i th asset should be larger than that on the j th asset. Second, concerning the effect of α on the risk weights,

$$\frac{\partial a_i^*}{\partial \alpha} = \frac{-}{\partial E^R} \cdot \frac{+}{\partial E^R} < 0 \quad \text{for all } i. \quad (11)$$

When the regulators want to decrease the upper bound on the probability of insolvency, they should raise the minimum capitalization rates.¹³ Graphically, the lower upper bound implies that the regulators' reference line $L_R: E = -1 - \Phi(\alpha) \cdot \sigma$ has a steeper slope. The intersection point of the steeper reference line and the frontier has a lower expected return. That is, the maximum allowable expected return should be lowered for the safer banking system. With the lower allowable return, the larger risk weights are required.

C. Potential Effects of the New Plan on the Banking Industry

When the optimal risk weights are imposed, it is obvious that the expected utility of (risky) banks will be lower than before. In this respect, the new plan alters the risky banking firms' choice between return and risk more severely than the uniform capital ratio regulation. Furthermore, investors will realize that the expected return on bank stocks is limited by E^R under the new plan. To the

¹² In terms of equation (5), if a bank capitalizes assets more than required, i.e., $a_i > a_i^*$ for any i , the strict inequality holds. Such a bank chooses a portfolio on G_0G_1 in Figure 2 and the new constraint is redundant.

¹³ However, it cannot be said that $(\partial a_i^* / \partial u_i) > 0$ because E^R also changes as u_i changes. The net impact of a change in u_i on a_i^* depends on the sensitivity of E^R (or change in the shape of the frontier) with respect to the u_i change.

extent that there exist other financial institutions that offer close substitutes for bank products but that are not subject to the same capital (and other bank) regulation, the banking industry will be adversely affected by the regulators' safety goal. Whether such a shift is desirable is difficult to evaluate. As Buser, Chen, and Kane [4] show, the current deposit pricing system benefits existing institutions. This shift to risk-related capital may just redress the mispricing of deposit insurance that heretofore has given the industry unfair advantage.

Another implication of the new plan will be a change in bank product pricing and investment policy, resulting in different credit allocation patterns. Since the new plan requires different capitalization rates for different assets, banks may try to charge higher rates on assets calling for a higher capitalization than before so that banks can get a proper return on equity capital. In addition, banks may hesitate to extend credit to projects with high risk weights, especially when other less regulated institutions offer similar products and thus banks cannot control the price of such assets. In this respect, the risk-related capital plan is a new form of asset regulation. While the Glass-Steagall Act restricts the types of bank assets, the new plan is designed to control the composition of the asset portfolio, so that the maximum attainable expected return on equity is bounded by E^R . Under the correct risk weights, banks would hold more liquid safe assets and less risky assets, which the regulators hope to achieve. As a result, the proposed capital regulation may lead to a substantial structural change in the financial service industry.

This latter point should be a cause for concern. It should be remembered that the current and proposed capital regulations are only concerned with the asset side of the bank balance sheet. The uniform ratio requirement specifies the minimum required equity capital relative to the size of the asset portfolio, while the risk-related plan tries to put restrictions on the composition of the asset portfolio and some contingent liabilities through the imposition of required capital on some off-balance-sheet activities. Both regulations treat deposits as if their costs had a zero correlation with included items. However, deposit costs tend to move in tandem with rates on other financial assets, generally showing a positive covariance with asset returns. This is especially so when we consider banks' prudent asset/liability management. When assets and liabilities have a positive covariance ($V_1 > 0$), the short sale of one asset (deposits) reduces the total portfolio variance, for any given expected return, relative to that of the zero-covariance case; i.e., from equation (1),

$$\sigma_k^2 |_{E_k=E, Y_1>0} < \sigma_k^2 |_{E_k=E, Y_1=0}. \quad (12)$$

Under the risk-related capital regulation procedures, the regulators tend to overestimate the portfolio variance by $2(1 - 1/k)V_1'X_1^*$ when they observe the bank portfolio X_1^* and, thus, tend to impose stricter restrictions than they should. The omission of liability structure from current capital regulation proposals implies that banking firms will be under unduly restrictive capital regulations, and this may lead them to alter their portfolio composition and asset pricing to a much larger degree than would be required if the regulators' solvency standard were more accurately imposed. The industry will suffer from more competitive

disadvantages over other competing financial institutions to the extent that there is a significant difference between frontiers perceived by regulators and banks.

III. Summary and Conclusion

The current deposit insurance pricing system encourages risk taking by the banking firm. Recently, the regulators have attempted to use capital standards to deter the industry from profiting from the inappropriate pricing of deposit insurance. However, these attempts have not always been well conceived. This paper investigates the effect of bank capital regulation on asset choice.

By applying the single-period mean-variance model, the effect of capital regulations on an optimizing banking firm is examined. We demonstrate that the traditional uniform capital ratio regulation is an ineffective way to control the probability of bank insolvency and, thus, to maintain a "safe and sound" banking system. The primary reason is that it ignores the individual banks' different preference structures and allows "risky" banks to circumvent the restrictions via financial leverage and/or business risk.

The recent move to the risk-related capital regulation is potentially more effective. However, to be successful requires that the weights be chosen optimally. We derive such weights. The "theoretically correct" risk weights derived in equation (9) provide an upper bound on insolvency probability. Interestingly, these weights are independent of bank preferences and thus may be effective in maintaining the regulators' safety goal. Furthermore, it is shown that the optimal risk weights depend only on three factors: (a) the expected returns, (b) their variance-covariance structure, and (c) the upper bound on the allowable insolvency risk the regulators have in mind. The regulators can determine the optimal risk weights specific to any bank(s) by observing the three factors and, thus, can limit the insolvency risk of all banks to an acceptable level, independently of preference structures. The straightforward nature of the optimal risk weight determination implies that their empirical estimation could be implemented and used to evaluate the regulators' risk weights. However, it should be noted that current policy by ignoring the liability side may result in unduly severe restrictions on bank activities.

The critical implication of the new plan is that it would put serious restrictions on bank activities and product pricing. Thus, the new plan could result in a significant structural change in the entire financial service industry.

Appendix

Derivation of the efficient frontier from equation (1) results in

$$E_k = E_{k.m} + (1/D) \cdot [W \cdot D \cdot (\sigma_k^2 - \sigma_{k.m}^2)]^{1/2} \quad (\text{A1})$$

where $(E_{k.m}, \sigma_{k.m}^2)$ represents the minimum-variance portfolio for a given k :

$$E_{k.m} = (1/k)(A/D) + (1/k - 1)(1/D)(DF - AG) - (1/k - 1)u_0,$$

$$\sigma_{k.m}^2 = (1 - 1/k)^2(\sigma_0^2 - H) + (1/D)[1/k - (1/k - 1)G]^2,$$

and

$$\begin{aligned} B &= \underline{U}'_1 \underline{\Omega} \underline{U}_1 > 0, & A &= \underline{e}' \underline{\Omega} \underline{U}_1, \\ D &= \underline{e}' \underline{\Omega} \underline{e} > 0, & W &= BD - A^2 > 0, \\ F &= \underline{U}'_1 \underline{\Omega} \underline{V}_1, & G &= \underline{e}' \underline{\Omega} \underline{V}_1, \\ H &= \underline{V}'_1 \underline{\Omega} \underline{V}_1 > 0, & \underline{\Omega} &= \underline{V}_2 \text{ inverse.} \end{aligned}$$

From (A1), we can show that, as leverage increases (larger $1/k$), the concave efficient frontier moves up and to the right in (E, σ) space and that the efficient frontier with an asset-to-capital ratio k_2 cuts from below one with a ratio k_1 when $k_1 > k_2$. The latter relationship can be proven as follows.

Define $T(\sigma) = E_{k_1} - E_{k_2}$, where E is defined according to (A1). For $\sigma > \sigma_{k_2.m} > \sigma_{k_1.m}$,

$$\frac{\partial T(\sigma)}{\partial \sigma} = \frac{W \cdot \sigma [(\sigma^2 - \sigma_{k_2.m}^2)^{1/2} - (\sigma^2 - \sigma_{k_1.m}^2)^{1/2}]}{(WD)^{1/2} [(\sigma^2 - \sigma_{k_1.m}^2) \cdot (\sigma^2 - \sigma_{k_2.m}^2)]^{1/2}} < 0.$$

Since $T'(\sigma) < 0$, E_{k_2} has a steeper slope everywhere than E_{k_1} in (E, σ) space. It implies that there is a σ such that $T(\sigma) = 0$ for $\sigma > \sigma_{k_2.m} > \sigma_{k_1.m}$.

The global efficient frontier can be obtained by choosing k to minimize the variance σ_k^2 for a given level of the expected return on equity capital. The global efficient frontier obtained with no restrictions on k is

$$E = \frac{\underline{U}' \underline{V}^- \underline{e}}{\underline{e}' \underline{V}^- \underline{e}} + \frac{1}{\underline{e}' \underline{V}^- \underline{e}} \cdot \left[Z \cdot (\underline{e}' \underline{V}^- \underline{e}) \cdot \left(\sigma^2 - \frac{1}{\underline{e}' \underline{V}^- \underline{e}} \right) \right]^{1/2},$$

where $Z = (\underline{U}' \underline{V}^- \underline{U}) (\underline{e}' \underline{V}^- \underline{e}) - (\underline{U}' \underline{V}^- \underline{e})^2 > 0$ and $\underline{U} = [u_0, \underline{U}'_1]$, which is exactly the same as the Merton [12] hyperbola.

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