Regulation of Bank Capital and Portfolio Risk
Author(s): Michael Koehn and Anthony M. Santomero
Source: *The Journal of Finance*, Vol. 35, No. 5 (Dec., 1980), pp. 1235-1244
Published by: Blackwell Publishing for the American Finance Association
Stable URL: http://www.jstor.org/stable/2327096
Accessed: 28/11/2009 08:22

THE JOURNAL OF FINANCE • VOL. XXXV, NO. 5 • DECEMBER 1980

Regulation of Bank Capital and Portfolio Risk

MICHAEL KOEHN and ANTHONY M. SANTOMERO*

Introduction

RECENT LARGE BANK FAILURES (e.g., Franklin National), coupled with an unstable economic environment, have rekindled the controversy over the adequacy of bank capital. There is, of course, an abundance of literature on both sides of the bank capital issue. Noticeably absent from the literature arguing for and against regulating bank capital, however, is a detailed consideration of the impact of such regulation on individual bank behavior and whether the regulation actually achieves its desired result.[1] Typically regulation is assumed to function in an essentially ceteris paribus environment, whereby the mere addition of capital to the bank's balance sheet reduces risk. The purpose of this paper is to examine explicitly the issue of portfolio reaction to capital requirements by investigating the effect of capital ratio regulation on the portfolio behavior of commercial banks.[2] Implicit in the analysis is the view that bank regulators presently do not constrain portfolio risk so as to prevent such asset reshuffling. Given the lack of objective standards or guidelines on asset portfolio risk, this approach seems more appropriate than to assume no asset portfolio response.

This paper examines the portfolio allocation that flows from the portfolio decision of the firm. Next it examines the effects on bank portfolio risk of a regulatory increase in the minimum capital asset ratio that is acceptable to the supervisory agency. For the system as a whole, the results of a higher required capital-asset ratio in terms of the average probability of failure are ambiguous,[3] while the intra-industry dispersion of the probability of failure unambiguously increases. This result leads us to question the viability of regulating commercial banks in terms of a capital requirement. Thus, serious consideration should be given to the discontinuance of regulation of bank capital via ratio constraints. Alternatively, regulation should be imposed on both asset composition and capital in a way that has heretofore not been considered.

* Arthur D. Little, Inc. and The Wharton School, University of Pennsylvania, respectively. The authors would like to thank the Rodney L. White Center for Financial Research for financial assistance. Also, thanks go to Mark Flannery.

[1] The only exception to this is a paper by Mingo and Wolkowitz [6]. However, this work neglects several essential features by assuming a linear utility function and a non-stochastic profit function.

[2] We will assume that regulators can enforce capital requirements and that the measure of adequacy used is the capital-risk asset ratio. See Santomero and Watson [12] and Wolkowitz [13] for a discussion of capital enforcement.

[3] The measure of the probability of failure comes from Roy [11].

I. The Model

The approach taken here is to examine the portfolio response of the commercial bank, when faced with a regulatory change. The major assumptions used to construct the model and to carry out the analysis are enumerated below:

a. Total bank size is assumed to be under the control of bank management. That is, the amount of deposits raised by management to support the purchase of risky assets is a choice variable,[4] as is the total amount of capital. However, it will be assumed that the ratio of capital assets is effectively constrained by regulation.

b. For simplicity, there does not exist a risk-free asset for purchase by the bank, but the return paid to depositors is riskless.[5]

c. The bank acts as if it were a single period risk averse expected utility maximizer;[6] the assumption of risk aversion in this context is well known in the literature (see D. Pyle [9], for example). Furthermore, Ross [10] has shown that an optimal fee schedule can be derived such that the agent, i.e., bank management, acting so as to maximize its expected utility, will maximize owners' expected utility. It is further assumed that the objective function can be approximated by a Taylor series expansion of a general class of risk averse utility functions, truncated after the second moment. Thus, the allocation across assets becomes the choice variable deriving the optimal mean rate of return per unit of capital and the variance of that return. Finally, the bank acts as if it is operating in a competitive market.[7]

Given that the regulator fixes the capital to asset ratio, denoted $c \equiv K/A$, the choice problem facing the bank is to determine (a) its optimal scale, i.e., the amounts of both deposits and capital to issue, and (b) the optimal allocation of this asset pool over the available risky asset set. However, given the competitive market assumption, the bank may issue any quantity of equity and deposits in the ratio of c to $(1 - c)$ respectively to proportionately increase total earnings; return and risk per unit of capital are unaffected by bank scale in the competitive market.[8] Therefore, the analysis will be developed in terms of risk and return per unit of capital with no loss in generality.

[4] It will be assumed the bank holds enough cash to satisfy reserve requirements as well as working cash needs. Cash holdings will subsequently be ignored.

[5] Effectively the bank issues the risk free asset in this model. If, alternatively, there existed another risk free asset, the portfolio decision as structured by traditional theory would reach a bounding conclusion. To arrive at an interior solution would require that the deposit rate fluctuate with size due to, e.g., default risk. However, this leads the analysis far afield and will be omitted here.

[6] See Michaelsen and Goshay [5]. There may be a question whether a bank should maximize market value or a concave utility function. If we assume that banks are closely held, then assuming risk aversion is not unreasonable. Furthermore, without a well-defined general equilibrium model of the capital markets, it is not clear how market value is determined. See D. Pyle [9], and O. Hart and D. Jaffee [2] for examples of the use of utility functions to describe intermediary behavior.

[7] Assuming a competitive market is not critical to the results of the paper. However, it makes for ease of derivation. See James [3] for a discussion of the impact of market imperfections on portfolio choice.

[8] In a more general model the existence of monopoly profits in some markets could derive an optimal bank size. For the present purposes, however, only the asset choice per unit of capital is required for the analysis.

To find the efficient investment set[9] the bank has the following quadratic programming problem, described in depth by Merton (4):

$$\text{minimize } \{x_i\} \qquad \tfrac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} x_i x_j \sigma_{ij} - \lambda_0 E_p \qquad \text{for all } \lambda_0,\ 0 \leqq \lambda_0 \leqq \infty \tag{1}$$

subject to

$$1 = \sum_{i=0}^{n} x_i \tag{2}$$

$$x_0 \geqq 1 - \frac{1}{c} \tag{3}$$

with

$$E_p = x_0 R + \sum_{i=1}^{n} x_i E_i \tag{4}$$

where

(a) E_i is the expected return on the i^{th} asset
(b) x_i is the percentage of equity value, as distinct from total portfolio value, invested in the i^{th} asset, $i = 1, 2, \cdots, n$.[10]
(c) σ_{ij} is the covariance of returns between the i^{th} and j^{th} assets, and the variance of return on the i^{th} asset is $\sigma_{ii} = \sigma_i^2$. We assume that the variance-covariance matrix is positive-definite.
(d) E_p and σ_p^2 are the expected return and variance of return, per unit of capital, on the bank portfolio.
(e) x_0 is the percentage of capital held in the negative asset (deposits) paying the risk-free rate R.
(f) λ_0 is the real tradeoff between variance and expected return at any point on the efficient investment frontier, i.e., $\lambda_0 = \dfrac{d\sigma_p^2}{dE_p}$.

Equation (3) represents the leverage or capital constraint imposed by regulation. As the value of c varies from zero to one, the leveraging potential of the bank varies from the bank's unconstrained optimum to an amount equal only to its equity capital. Thus, for example, when $c = 1$, the bank acts like a mutual fund unable to issue deposits of any kind; likewise, if $c = .10$, then the maximum proportion of equity which can take the form of deposit liabilities in the bank portfolio is $x_0 = -9$. That is, the bank can issue liabilities up to 900% of its equity capital, and thus leverage its risky asset portfolio to an amount far greater than its equity. Since interest centers upon the impact of a marginal change in c on bank portfolio behavior, it will be assumed that x_0 is constrained to $1 - \dfrac{1}{c}$, i.e., the leverage of the bank is constrained by c.

[9] The efficient frontier is made up of portfolios with maximum expected return for all possible levels of variance. See Merton [4].

[10] We will neglect the effects on solvency and bank behavior if certain assets are restricted from purchase by regulation.

The first order conditions for the minimization are:

$$\sum_{j=1}^{n} x_i \sigma_{ij} - \lambda_0 E_i - \lambda_1 = 0 \qquad i = 1, 2, \cdots, n \tag{5}$$

$$-\lambda_0 R - \lambda_1 - \lambda_2 = 0 \tag{6}$$

$$1 - x_0 - \sum_{j=1}^{n} x_i = 0 \tag{7}$$

$$1 - x_0 - \frac{1}{c} = 0. \tag{8}$$

The solution to the above system of equations is unique and will minimize equation (1) by the assumption that the variance-covariance matrix is positive-definite. The particular portfolio chosen by the bank, given that it is constrained by c, is obtained by the simultaneous solution of equations (5) to (8) and the equality of λ_0 to the marginal rate of substitution between risk and return dictated by the bank's objective function.

To obtain a unique portfolio of the firm, we will assume that the bank has a general risk averse utility function in end-of-period capital. For a given value of initial capital, the objective function can be written as:

$$U = U(K + R_p K). \tag{9}$$

Taking a Taylor expansion of equation (9) around initial capital of the bank, neglecting higher order terms (see Pratt[11]) and taking the expected value yields equation (10).

$$E(U) = U(K) + U'(K)[E(R_p) - b\{(E(R_p))^2 + \sigma_p^2\}] \tag{10}$$

where $b = -\dfrac{U''(K)K}{2U'(K)}$, the coefficient of relative risk aversion of the underlying utility function. For this objective function, the marginal rate of substitution between risk defined as the variance of portfolio return, and expected return is,

$$\left.\frac{d\sigma_p^2}{dE_p}\right|_{u=\bar{u}} = \frac{1}{b} - 2E_p = MRS_{\sigma_p^2, E_p}. \tag{11}$$

Since optimality requires equality of the MRS to the objective tradeoff of risk and return, the following condition must be satisfied for the optimal portfolio, viz.

$$\frac{1}{b} - 2E_p = \lambda_0. \tag{12}$$

Following the approach used by Merton [4] the quantity of each asset per unit of capital can be derived:

$$x_i^* = \frac{AC\left(\frac{1}{b} - 2R\right) - C(1+B)\frac{1}{c}}{C+D}\left[\frac{\sum_{j=1}^n (E_j - R)v_{ij}}{A} - \frac{\sum_{j=1}^n v_{ij}}{C}\right] + \frac{\sum_{j=1}^n v_{ij}(E_j - R)\frac{1}{c}}{A} \qquad i = 1, 2, \cdots, n \quad (13)$$

where:[11]

$$A = \sum_i \sum_j v_{ij}(E_j - R), \qquad C = \sum_i \sum_j v_{ij} > 0,$$

$$B = \sum_j \sum_i v_{ij}(E_i - R)(E_j - R) > 0, \qquad D = BC - A^2 > 0$$

Equation (13) represents the optimal ratio of each risky asset in the portfolio to equity capital, expressed in terms of the parameters of the joint distribution of returns, the value b of the utility function and the capital asset constraint, c.

Now consider an increase in c. From the budget constraint, equation (7), and the capital constraint, equation (8), it is clear that the bank will be unable to leverage its capital to the degree it had prior to the increase in c. Moreover, because of the new more stringent restriction on the leveraging capability of the bank, the bank's efficient investment frontier falls downward and to the left for any given value of capital. Thus, over the entire frontier[12]:

$$\frac{\partial \sigma_p^2}{\partial c} < 0, \frac{\partial E_p}{\partial c} < 0.$$

This implies unambiguously that over the entire permissable efficient frontier the total variance of the portfolios fall and the return on each set declines.

However, with the imposition of higher capital requirements, the bank reacts by reshuffling the composition of its asset portfolio per unit of capital. The effect on the composition of the bank's portfolio, given a small change in the required capital-asset ratio, can be evaluated by differentiating equations (13) with respect to c. If it is assumed that the utility function exhibits constant relative risk aversion,[13] the result may be written in elasticity form as:

$$\epsilon_{x_i,c} = \frac{1}{x_i}\frac{\left(\frac{1}{c} - 2R\right)(AC)}{C+D}\left[\frac{\sum_j^n v_{ij}(E_j - R)}{A} - \frac{\sum_j^n v_{ij}}{C}\right] - 1, \quad i = 1, \cdots, n \quad (14)$$

[11] See Merton [4] for proof of the following inequalities. The inequalities result from the fact that the inverse of the variance-covariance matrix is positive-definite.

[12] To show the sign of these derivatives, differentiate σ_p^2, and E_p with respect to c, using the definitions of σ_p^2 and E_p.

[13] An increase in the required c ratio will reduce the value of current period wealth, K, defined as the capitalized returns from bank equity ownership. If the utility function exhibits constant relative risk aversion, the *MRS* will be unaffected by the change in regulation. The implications of a utility function with decreasing relative risk aversion are treated below. See footnote *14*.

Equation (14) is the elasticity of proportional demand for the ith asset with respect to the capital-asset constraint, evaluated at the optimum.

It is easy to show that the relative size of the elasticity expression for every asset is determined by the asset's risk contribution to the optimal portfolio. Risk contribution is defined as σ_{ip} so that $\epsilon_{x_i,c} > \epsilon_{x_j,c}$ if $\sigma_{ip} > \sigma_{jp}$. This proof, available from the authors, follows directly from the work of Merton [4] and is not repeated here. This result gives the following interpretation. Subsequent to the imposition of a decreasing leveraging capability, i.e., an increasing c, the reaction of the bank is to reshuffle its portfolio. The composition of the resulting equilibrium portfolio after the increase in c is described by relatively more risky assets than before the increase.[14] The effect of an increased c on the bank portfolio is, thus, somewhat contrary to the desired result.

It can be shown from equation (14) that the degree to which this reshuffling occurs is dependent upon the risk aversion coefficient, b. For highly risk averse institutions, the elasticity value of high risk assets is less than the elasticity for other institutions possessing less risk aversion. Likewise, the conservative institution will shift its portfolio from low risk to a lesser degree than its risk taking counterparts. It follows, therefore, that institutions which initially held relatively more risky assets per unit of capital, shift to offset the capital restriction to a greater extent than do the more conservative group of firms. Consequently the dispersion of risk taking across the banking industry expands. That is, relatively, conservative institutions somewhat offset the capital restrictions. However, their more risky counterparts, on the other hand, reshuffle their balance sheet to an even greater extent and therefore increase the variance of total risk for the entire industry. The effect of this adjustment on the industry's probability of failure will be the next area of concern.

II. Capital Regulation and Bankruptcy

It will be assumed that the central purpose of bank regulation is to reduce the riskiness of the bank portfolio so as to reduce the probability of failure. While some arguments to the contrary may be offered, the alleged purpose of regulatory control over these institutions has been to increase stability and viability.

An explicit relationship between the risk of the bank portfolio, the amount of bank capital held and the chance of bankruptcy must, therefore, be obtained to evaluate the result of bank capital regulation. Such a relationship may be accomplished once the characteristics of the distribution of the returns from bank operations has been defined. There are essentially two choices. Either the distribution can be assumed to be known, e.g., using a normality assumption, or left indeterminant, e.g., using some general probability characteristics. In either case, the analytic results indicated below will immediately follow. For simplicity, therefore, the major part of the analysis will make reference only to Chebyshev's Inequality.

[14] If the utility function exhibits decreasing relative risk aversion, this shift into riskier assets is reinforced as the reduced value of expected terminal capital reduces b in equation (11) above.

The capital-asset ratio, the expected return of the portfolio, and the variance of the return can be utilized, via the Chebyshev Inequality, to estimate the upper bound of the probability of failure, as suggested by Roy [11] and Blair and Heggestad [1].[15] Given the characteristics of the bank portfolio described by E_p and σ_p, this upper bound may be written as:[16]

$$PR[\tilde{R}_p < -1] \leqq \frac{\sigma_p^2}{(E_p + 1)^2} = P, \tag{15}$$

As expected, an increase in variance increases the probability of failure, while an increase in returns or the capital ratio will, ceteris paribus, decrease failure risk.[17]

Graphically, this upper bound on the probability of failure can be seen as the square of the reciprocal of the slope of a ray in mean variance space.[18] The ray has an intercept of $[-1]$ in Figure 1 and is denoted as D_0. It intercepts the efficient frontier at point Z_0, where the optimal allocation is indicated by the tangency of the objective function. The portfolio at point Z_0 is characterized by the proportions x_i $(i = 1, \cdots, n)$ or equations (13), and E_p^* and σ_p^*. The firm's portfolio has an upper limit on its probability of failure of P which is constant along the D_0 ray.

If bank regulators impose a higher c, the frontier moves down and to the left. If the bank settles for the same risk-return trade-off in its portfolio as initially, the portfolio set will shift to Z_1 on the new constrained frontier. Since the slope of D_1 through Z_1 is greater than the slope of D_0, the upper bound of the probability of failure decreases and the regulators achieve their desired result.

However, a bank satisfying the conditions set above, will not move to point Z_1. That is, the portfolio Z_1 (identical in risk-return trade-off to portfolio Z_0) will not become the equilibrium portfolio of the bank. Recall that subsequent to the increase in c, the bank reshuffles its portfolio towards relatively more risky assets. This shifts the tangency point from Z_1 in Figure 1 to a point of higher risk and return. The exact point will, as noted above, be dependent upon the risk aversion factor of the institution's preference function.

Two cases can be distinguished and are pictured also in Figure 1. In the first of these the new portfolio choice results in a reduction in the probability of failure, even though some asset reallocation has occurred. This is denoted by Z_2 and lies to the left of D_0 but to the right of Z_1. In contrast, Z_3 lies to the right, indicating that, for this institution, the probability of failure has increased as a result of increasing required capital.

To explain the differing results, reference must be made to the portfolio

[15] Blair and Heggestad's model is an application of Roy's [11] Safety First Model.

[16] Following Blair and Heggestad, the Chebyshev Inequality states

$$PR[\tilde{R}_p - E_p > k\sigma_p] \leq \frac{1}{k^2}.$$

$$\text{Let} \quad -1 = E_p - k\sigma_p, \quad \text{so } k = \frac{E_p + 1}{\sigma_p}.$$

[17] This will allow for a monotonic failure locus and all other results obtained. A normal distribution, as well as most others used in portfolio theory, would satisfy these conditions.

[18] See Roy [11] for a proof of this, or Blair and Heggestad [1] for a thorough discussion.

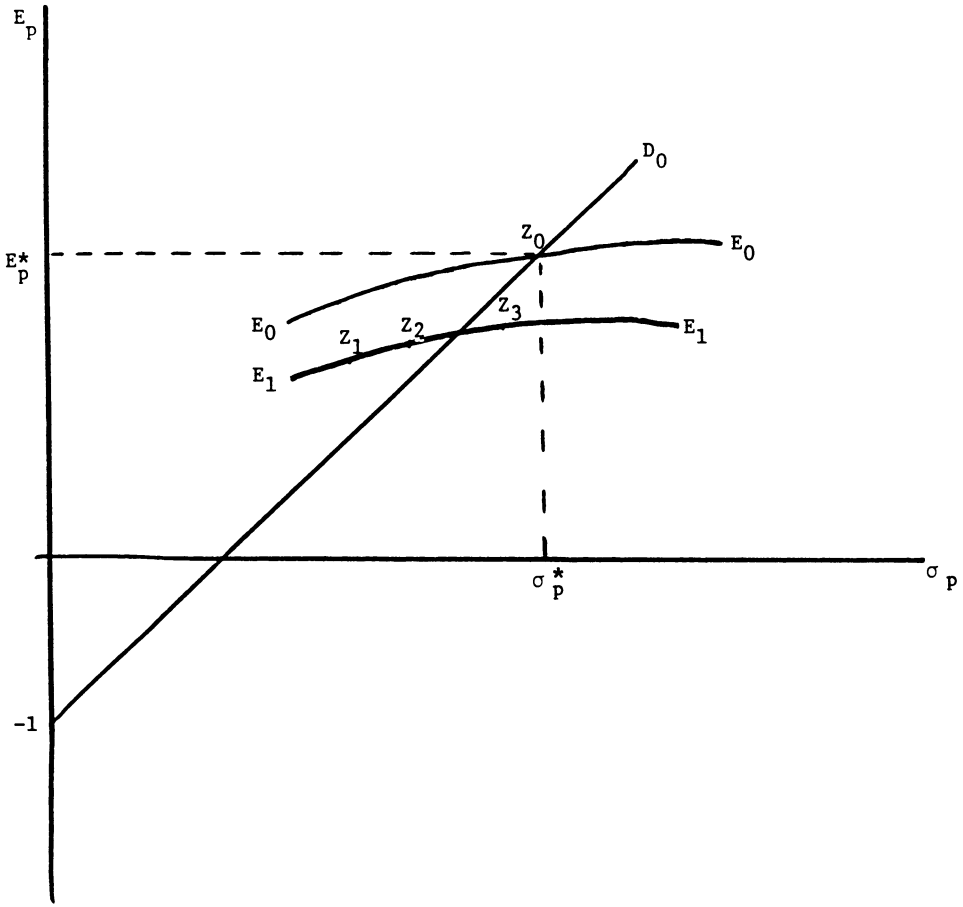

Figure 1. The effect of a reduction in allowable leverage.

E_p = the return per unit of capital on the portfolio.
σ_p = standard deviation per unit of capital on the portfolio.
E_0E_0 = initial allowable efficient frontier.
E_1E_1 = newly constrained efficient frontier.
Z_0 = initial optimum.
Z_1 = point on E_1E_1 with identical MRS as Z_0.

decision model of the previous section. Examination of equation (14) reveals that, for an institution with a smaller value of b, the bank's reaction to an increase in c is a larger shift towards riskier assets which more than offsets the effect of increasing c. Therefore, the chance of failure increases. Conversely, if the bank is sufficiently risk averse, i.e., b is sufficiently large, then the movement towards riskier securities will be small, relative to the increase in c. In this case, the chance of failure decreases.[19]

[19] As noted in footnote 14, b falls as c is increased in the case where the utility function exhibits decreasing relative risk aversion. This fosters even further movement up the new efficient frontier and favors the more extreme readjustment indicated by a shift to point Z_3 in Figure I.

This point may be seen analytically be examining the effect of variance reduction for institutions with different risk aversion coefficients, viz., $\dfrac{d\left(\dfrac{d\sigma_p^2}{-dc}\right)}{db} > 0$. Thus, σ_p^2 declines for every bank's portfolio, but the absolute magnitude of the decline depends upon b. However, if b is sufficiently small, the fall in E_p along with the reshuffling of the portfolio implies that the chance of failure increases.

Notice that the rank ordering of the increase in the relative holdings of the risky assets associated with a higher capital requirement is identical to the risk ordering of the institutions' portfolios before regulation. A frequency distribution of the probability of failure for the entire industry will accordingly be equivalent to a frequency distribution of risk aversion coefficients. If regulation is now imposed so as to uniformly increase the capital requirements of the industry, offsetting reshuffling of the risk-asset components of the portfolio will occur based upon this same value, b. Risky institutions will react more to thwart the regulatory intent than relatively safer institutions.

From the above argument, therefore, it is clear that there exists some value of b, denoted b^*, below which any increase in c will increase the probability of bankruptcy, rather than decrease it as assumed. Thus as the capital constraint increases, the probability of failure will decrease, increase or remain unchanged as b is greater than, less than or equal to the critical value b^*. The final distribution of risk of failure for the banking industry will therefore possess a higher dispersion than before the imposition of regulation. Essentially, the relatively safe banks become safer, while risky institutions increase their risk position. The mean of the industry is dependent upon the underlying distribution of risk aversion, b.

If capital constraints are only imposed on a certain subset of the industry, the prognosis is no better. The banks likely to be subjected to a higher required c are ones that are less risk averse, i.e., a low value of b. In other words, one would expect that a less risk averse bank would hold risky securities and therefore would be closely watched by regulators. However, the imposition of a higher required capital-asset ratio on these banks may well have a perverse effect. For such banks, it would seem that the regulators should find some other instrument to control the probability of failure, such as asset restrictions, or abandon attempts that essentially prove counterproductive. Regulating bank capital through ratio constraints, therefore, appears to be an inadequate tool to control the riskiness of banks and the probability of failure.

III. Summary

Regulatory constraints that impinge upon bank behavior are designed—excluding from consideration questions of monetary policy—(a) to protect depositors, and (b) to protect the banking system as a whole. The rationale given for these restrictions including capital constraints usually points to the lower probability of failure that will result when these constraints are binding. However, as was demonstrated above, this is not what necessarily obtains. In fact, a case could be argued that the opposite result can be expected to that which is desired when higher capital requirements are imposed.

It is interesting to note that a number of researchers have not found an explicit relationship between bank failure and the amount of capital held.[20] The model presented above explains why this might be the case, for it includes consideration of the reaction of the institution to new regulatory stringency. This implies that the result of such regulation may be the opposite of regulatory intent.

REFERENCES

1. R. Blair and A. Heggestad, "Bank Portfolio Regulation and the Probability of Bank Failure," *Journal of Money, Credit and Banking* (1978).
2. O. Hart and D. Jaffee, "On the Application of Portfolio Theory to Depository Financial Intermediaries," *Review of Economic Studies* (January, 1974).
3. John A. James, "Portfolio Selection with an Imperfect Competitive Asset Market," *Journal of Financial and Quantitative Analysis* (December, 1976).
4. R. Merton, "An Analytic Derivation of the Efficient Portfolio Frontier," *Journal of Financial and Quantitative Analysis* (December, 1972).
5. J. Michaelsen and R. Goshay, "Portfolio Selection in Financial Intermediaries: A New Approach," *Journal of Financial and Quantitative Analysis* (June, 1967).
6. J. Mingo and B. Wolkowitz, "The Effects of Regulation on Bank Portfolios, Capital and Profitability," *Conference on Bank Structure and Competition*, Federal Reserve Bank of Chicago (1974).
7. S. Peltzman, "Capital Investment in Commercial Banking and Its Relationship to Portfolio Regulation" *Journal of Political Economy* (1970).
8. J. W. Pratt, "Risk Aversion in the Small and in the Large," *Econometrica* (January, 1964).
9. D. Pyle, "On the Theory of Financial Intermediation," *Journal of Finance* (June, 1971).
10. S. Ross, "The Economic Theory of Agency: The Principal's Problem," *American Economic Review* (May, 1973).
11. A. Roy, "Safety First and the Holding of Assets," *Econometrica* (July, 1952).
12. A. Santomero and R. Watson, "Determining the Optimal Capital Standards for the Banking Industry," *Journal of Finance* (September, 1977).
13. B. Wolkowitz, "Measuring Bank Soundness," in Proceedings of *Conference on Bank Structure and Competition*, Federal Reserve Bank of Chicago (May, 1975).

[20] See S. Peltzman [7] for example.