A Limit-Risk Capital Adequacy Rule: An Alternative Approach to Capital Adequacy Regulation for Banks with an Empirical Application to Switzerland

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1. INTRODUCTION

Capital adequacy rules have stood at the forefront of regulatory change in banking in the past decade. Ever since the third-world debt crises in the early 1980s, when defaulting LDC debtors drove many banks on or over the brink of bankruptcy, representatives of the bank supervisory authorities and the central banks of the G10 countries and of Switzerland and Luxembourg, meeting in the Basle Committee on Banking Supervision under the auspices of the Bank for International Settlements (BIS), have increased their efforts to establish a common set of minimum capital standards for banks. The work of the Committee seeks to serve two aims:¹ to strengthen the soundness and stability of the international banking system and to ensure that competition among banks of different countries is not «distorted» by national differences in regulatory requirements – the aim of the so-called «level playing field».

To date, the Basle Committee has issued two packages of capital guidelines. The first set, known as the Basle Capital Accord,² appeared in 1988 and fixed capital standards for the credit, or default risks of the on and off-balance-sheet assets of banks. These standards went into full effect internationally at the end of 1992.

The second set of guidelines is contained in the recently released Planned Supplement to the Capital Accord³ and covers market risks, or the chance of loss due to adverse movements of the market prices of bank-held assets. The guidelines in the Supplement constitute proposals. Comments are invited until the end of July 1995. The Committee envisages completing the final accord by the end of 1995 and having it go into full effect by end-1997. The guidelines of both the 1988 Accord and the Supplement present

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Without wishing to implicate them I should like to thank ERNST BALTENSPERGER, NIKLAUS BLATTNER, ROLF ENDERLI, THOMAS GEHRIG, HANS GEORSBACH, URS GRAF, MARTIN HELLWIG, WERNER HERMANN, JOSEF WILLIMANN and WALTER WIRSIG for helpful discussions. Thanks are also due my two discussants, GÜNTER FRANKE and DANIEL ZUBERBÖHLER. Financial support of the Swiss Bankers Association is gratefully acknowledged.

2. Cited in this paper as Basle Committee (1991).
minimum capital standards that can be exceeded by national supervisory authorities as they see fit.

A number of aspects of the Committee’s guidelines have been discussed critically in the literature. The commentary touches upon such issues as the «Why» of capital regulation for banks, the form such regulations should take, and the adverse or unintended effects they engender. The following paper focuses on two aspects of the guidelines that pertain to their stochastic underpinnings. For one, the paper demonstrates that although the capital guidelines are intended to lessen the probability of a bank failure, they provide scant clues as to the level to which their implementation would, in principle, lower the insolvency risk of a bank. Furthermore, the paper shows that the approach followed by the Committee of imposing separate capital charges for credit risks and market risks runs counter to one of the basic theorems of probability theory. As a result the BIS guidelines tend to lead to «overcharging». Both lines of criticism are discussed in more detail in section 2 of this paper.

Section 3 presents an alternative approach to capital adequacy regulation that aims to avoid the shortcomings of the BIS guidelines spelled out in section 2. In a sense, the suggested approach extends the value-at-risk (VAR) approach, recommended in the 1995 Supplement for assessing market risk, to credit risk, while at the same time dropping the distinction the guidelines draw between the two types of risks. In other words, the proposed approach does not represent a radical break with the current BIS guidelines. The approach also borrows from concepts employed in the actuarial sciences. This should come as no surprise given that regulators view bank capital as a means to insure depositors against loss. In fact, a deposit insurance system that charged «fair», or experience-rated premiums would essentially follow the same procedures outlined in section 3 of the paper.

The approach proposes requiring banks to hold enough capital to ensure that the insolvency probability of a bank does not exceed a pre-defined uniform limit. Section 3 demonstrates how this limit-risk-based concept can be used both to assess the costs and benefits of capital requirements as well as to calculate the probability that the insolvency of one bank could trigger a chain reaction (contagion risk). Section 3 also discusses some of the problems involved in implementing a limit-risk-based concept.

Section 4 of the paper applies the proposed concept to the Swiss banking sector. It investigates empirically to what extent current Swiss capital requirements, though perhaps unintended, nevertheless effect a uniform upper limit on the insolvency risks of banks. In addition, section 4 examines to what degree Swiss banks could currently meet limit-risk-based capital requirements and estimates the expected loss to depositors, conditional on bank default, that limit-risk-based capital requirements would imply.

Section 5 summarizes our findings and discusses their policy implications.

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2. **BIS GUIDELINES**

2.1. *Basle Capital Accord of 1988*

The 1988 Basle Accord, as previously mentioned, applies to the credit, or default risk of banks' on and off-balance-sheet assets. Credit risk stems from the possibility that a counterparty may renege on contract obligations. The Accord bases its method of assessing the capital requirements pertaining to credit risk on the so-called risk asset ratio (RAR) approach. The RAR procedure is essentially the same as that introduced by the Federal Reserve Board in 1956 and known as the ABC (Analysis of Bank Capital) approach. It is currently the chosen method of national supervisory authorities worldwide to assess the capital adequacy of commercial banks (GARDENER, 1992, p. 3).

The RAR approach is, in principle, easy to apply, which perhaps explains its widespread popularity among bank regulators. As implemented in the 1988 Basle Accord, the RAR approach divides the on and off-balance-sheet assets of a bank into five broad risk classes, \( a_j \) \((j = 1, \ldots, 5)\), and assigns each category a risk weight, \( w_j \), intended to reflect the relative credit risk of the assets belonging to the category. The weights range from 0 to 1, with assets deemed to be relatively risk-free (e.g., cash) drawing a weight of zero, and those considered to exhibit greater risk carrying a heavier weight. In effect, the risk weights act as discounting factors, writing off assets in inverse proportion to their perceived level of risk.

The Accord stipulates that a bank back up a fixed share (capital charge) of the risk weighted sum of its assets with its own capital \( C \). For a bank \( i \) this implies

\[
\text{(capital charge)}_i = C_i / a_i' w,
\]

where \( a_i \) = column vector containing the assets held by bank \( i \), divided into the five risk categories, and

\( w \) = column vector of uniform risk weights for all banks. Hence \( w \) appears without an index.

The Accord distinguishes between two categories of capital, Tier 1 and Tier 2. Tier 1, or so-called core capital consists essentially of equity capital and published reserves, while Tier 2 funds principally encompass subordinated debt and loan loss reserves. The BIS guidelines require a bank to hold at least 8 percent of its risk-weighted assets in the form of capital, 50 percent of which must consist of core capital.

As indicated by (1), the RAR approach – like the portfolio theory – links the credit risk exposure of banks to the composition of their asset portfolios. Accordingly, bank portfolios with greater perceived risk are assessed higher capital charges.
2.2. 1995 Supplement to the Capital Accord

The Supplement to the 1988 Basle Accord extends the guidelines of the original Accord to cover market risks, or those risks due to adverse movements of the market prices of bank-held assets. However, unlike the 1988 Accord, the Supplement allows banks to choose between two methods for calculating their capital charge. They can employ either their own in-house financial models or a so-called standardized measurement method, which is essentially an extension of the RAR approach.

Most banks' in-house models calculate a «value at risk» (VAR). This is the maximum loss of value a bank's portfolio of assets \( A \) could suffer over a given time period with a pre-defined occurrence probability \( P \). The VAR of a given bank \( i \) is calculated as:

\[
VAR_i = - F_i^{-1}(P) \cdot \sigma(A_i),
\]

(2)

where \( F_i^{-1} \) = inverse function of the probability distribution \( F^5 \) of \( A \) for bank \( i \) and

\[
\sigma(A_i) = \text{standard deviation of the future value of } A_i.
\]

The inverse function translates a given probability \( P \) into a corresponding number of standard deviations below the current value of the bank’s portfolio of assets. Multiplying the negative value\(^6\) of the number of standard deviations by the standard deviation (volatility) of the future value of the bank’s portfolio produces the VAR of the bank. The method is easily illustrated with a numerical example. Under the assumption that the future value \( A \) of a portfolio of assets is normally distributed around its current value with a standard deviation \( \sigma \) of $100,000 and that the pre-defined level of probability \( P \) is set at 1 percent, VAR is equal to $233,000. In other words, in 99 cases out of 100 the value of the portfolio at a fixed date in the future should lie no more than $233,000 below its current market value, given the development of market prices in the past. Portfolios whose values fluctuate by more have wider distributions, i.e., larger standard deviations, and according to (2) stand to incur greater losses with the same probability of occurrence.

It is important to note that VAR is not a prediction of how high losses, if any, will be, but rather a threshold which losses will not exceed with a given probability, based on the fluctuation of asset values in the past.

The Supplement stipulates that banks should assume an occurrence probability of 1 percent and a holding period of two weeks in their VAR calculations. The assumption of a two-week holding period is intended to guard against the possibility that a bank might not be able to unwind a position more quickly.

5. In the following, \( F \) pertains to standardized values of the random variable concerned.
6. Since VAR refers to a loss, i.e., a negative return, the value of the inverse function must be multiplied by minus one in order to obtain a positive value for VAR.
The Supplement requires banks to hold capital equal to at least three times VAR. Banks whose internal VAR calculations are deemed to be less accurate by the supervisory authorities are subject to a higher multiplication factor in the hope that this will encourage banks to improve the precision of their VAR models.

The standardized measurement method, presented in the Supplement as an alternative to the VAR method, distinguishes between four types of market risks: a foreign exchange risk, a commodities risk, and two further risks pertaining respectively to debt securities and to equities in the trading book. Each risk entails a separate capital charge. As a consequence, the standardized measurement method, unlike the RAR approach, subjects a single bank-held asset to up to three capital charges. Opting for the VAR method does not eliminate «double-charging» completely, as the guidelines of the 1988 Basle Accord still apply to any credit risk to which a bank-held asset may be exposed (Basle Committee, 1995, p. 7).

2.3. Assessment

The BIS capital adequacy guidelines have brought undisputed improvements. For one, the RAR approach represents a clear gain over traditional gearing ratios, that consider only the liabilities side of a bank’s balance sheet and thus encourage banks to meet their capital requirements by increasing their returns without paying heed to volatility. Such behavior leads to greater instability, when in fact the opposite is intended. The RAR approach has the added advantage that it is easy to understand and, in principle, not difficult to implement.

Despite its risk orientation, the RAR approach has been criticized for taking scant notice of the advances achieved in finance and portfolio theory in the past 45 years. Indeed, the RAR approach dates back to 1956. Yet now that the BIS guidelines accept the VAR approach, much of the criticism stemming from finance theory will undoubtedly subside. Nonetheless, the guidelines’ handling of risk still has its shortcomings. This paper addresses two difficulties. These can be summarized as follows.

- The design of the BIS guidelines does not conform fully to the guidelines’ objectives. The BIS proposals aim to strengthen the soundness and stability of banks. Yet they provide almost no indication of the level of insolvency risk they engender. Consequently, supervisory authorities lack a basis for deciding whether the level of soundness and stability achieved through the guidelines meets with their objectives. Hence, the level of capital charges chosen by the regulators is essentially arbitrary.
- The use of risk-specific capital charges, as opposed to asset-specific ones, conflicts with a basic law of probability. This tends to lead to overcharging for risk, a criticism — incidentally — that is independent of the critique pertaining to the degree of correlation between the returns of bank-held assets, which the RAR approach implicitly assumes to be perfect.
We elaborate on the first line of criticism first and begin with the RAR approach. To start, we observe that a bank $i$ is insolvent by definition when its losses exceed its capital $C$. That is, when

$$\text{profits}_i \text{ or } \pi_i < -C_i.$$  

(3)

Under the assumption that the level of profits that the bank realizes is uncertain and that its capital position is initially given, the probability $P$ that the bank will fail at the moment profits are realized will be a function of its capital position and of the variation, or uncertainty of its income. Hence

$$P(\text{bank failure}) = P(\pi_i < -C_i) = F_i \left( \frac{-C_i - E(\pi_i)}{\sigma(\pi_i)} \right)$$

(4)

where $F$ = probability distribution function for standardized values of $\pi_i$, $E$ = expected-value operator, and $\sigma$ = standard deviation of $\pi_i$.

The fraction enclosed in the outermost brackets measures the number of standard deviations that the profits of the bank would need to fall below their expected value for the bank to be insolvent. The function $F$ yields the probability of such an event occurring.

In the event that the returns of the assets held by the bank are perfectly correlated, as the RAR approach implicitly assumes, the standard deviation of the total returns of the bank is equal to a weighted sum of the standard deviations of the returns of each bank-held asset category, or

$$\sigma(\pi_i) = a_i'\sigma_i,$$  

(5)

where $a_i$ again represents a column vector of asset values, and $\sigma_i$ symbolizes a column vector containing asset-specific standard deviations of returns. Inserting (5) into (4) yields

$$P(\text{bank failure}) = F_i \left( \frac{-C_i - E(\pi_i)}{a_i'\sigma_i} \right)$$

(6)

Comparing (6) and (1) suggests that

$$P(\text{bank failure}) = F_i \{ -\text{capital charge} - E(\pi_i) / a_i'\sigma_i \},$$

(7)

7. We assume that the supervisory authorities close a bank the moment inequality (3) holds.
where it is assumed that the risk weights $w$ in the RAR formula correspond to the standard deviations $\sigma_i$ of the asset returns.

As the bank-specific index in (7) indicates, the application of the RAR approach does not yield a uniform maximum default probability for all banks, unless the total returns of each bank vary according to the same class of probability distributions $F$ and have an identical expected value and standard deviation. Whether the former holds in reality is uncertain. But the latter definitely does not, as section 4.2.1 will show.

In short, the RAR approach can imply a certain probability of bank failure if one is willing to assume that the asset returns of a bank are perfectly correlated. However, even then the implied level of insolvency risk varies across banks. Hence, the level of stability and soundness RAR-based capital requirements impart to banks is essentially unknown.

The VAR approach, on the other hand, does yield a uniform probability of failure for all banks if (i), as the Supplement envisages, a uniform holding period and occurrence probability are imposed, (ii) the capital requirement is set equal to VAR, and (iii), for the sake of simplicity, VAR applies to all bank-held assets. In this case, the probability of a bank failure is equal to the pre-defined occurrence probability $P$. In other words, based on (2)

$$P(\text{bank failure}) = F_i[-VAR_i/\sigma(A_i)]$$

Note that the left-hand side of the above equation is not indexed by $i$. This is a consequence of the uniform occurrence probability that the Supplement imposes and that holds no matter what the indexed terms in (8) may be for a bank. Note also that (8) closely corresponds to (4), except that the expected value of VAR appears to be missing in (8). Actually it is not missing, but equals zero by definition.

In contrast to our assumption that capital charges are equal to VAR, the Supplement requires banks to hold capital equal to at least three times VAR. As a result, the probability of a failure is no longer uniform for all banks unless the VAR of all banks have the same distribution function $F$, and even then $F$ must be known in order to determine the probability of insolvency. Under the assumption that VAR is normally distributed, a common premise in finance theory, multiplying VAR by three, as the Supplement proposes, lowers the failure probability from 1 percent to ten trillionths of 1 percent, or to a level of risk far lower than the Committee could possibly intend.

It is interesting to note, however, that if all banks incorrectly based their VAR calculations on the normal distribution, the multiplication of this falsely derived VAR by three would ensure that no matter for which bank what distribution is actually correct,

8. A further implication of a uniform occurrence probability for all banks is that the fraction in (8) enclosed in square brackets, i.e., the VAR measured in standard deviations is equal for all banks. The numerator and denominator may differ by bank, however, as long as the ratio remains unchanged.
the probability that a bank could fail would not exceed 1 percent. This follows from the CHEBYCHEV inequality.

The CHEBYCHEV inequality is a theorem of probability theory that states that the probability that a given random variable diverges from its expected value by \( z \) standard deviations is at most \( (z)^2 \), no matter how the random variable is distributed.\(^9\) In equation (8) the fraction in brackets corresponds to \(-z\).\(^10\) Under the assumption that all banks' VAR calculations are based on a normal distribution and on an occurrence probability of 1 percent, \(-z\) in (8) will equal 2.33. Were the banks, in this case, to multiply VAR by three, as the Supplement stipulates, \(-z\) would increase to 6.99. According to the CHEBYCHEV inequality the probability that a random variable diverges 6.99 standard deviations above or below its expected value is equal to 2 percent.\(^11\) However, VAR pertains only to losses, i.e., to fluctuations below the expected value. Hence we are only interested in negative divergence. Under the assumption that the true distribution of VAR, although unknown, is at least symmetrical, dividing the above probability by two yields an upper limit on the risk of insolvency of 1 percent.

In short, multiplying VAR by three under the circumstances stated corresponds to replacing the assumption of a normal distribution by the more robust CHEBYCHEV inequality. Whether the thinking of the Committee is based on this relationship is unknown, but it does provide a rationale for choosing three as the multiplication factor.

We now turn to the second line of criticism, i.e., the claim that the imposition of risk-specific capital charges leads to «double-charging». From the standpoint of the BIS guidelines, equations (4), (6), and (7) above pertain to the probability of a bank insolvency due to credit risk, while equation (8) refers to the probability of a bank failure as a result of market risk. The guidelines assign a separate capital charge to each risk, and the total capital charge results from adding both charges together. Calculating the capital charges in this additive manner implies that in the eyes of the Basle Committee, the probability of a bank failure per se, whether it result from credit risk and/or market risk, is equal to the sum of both probabilities. That is,

\[
P(\text{bank failure per se}) = P(A) + P(B),
\]

where \( A \) = bank failure due to counterparty default (credit risk) and
\( B \) = bank failure due to adverse price movements (market risk).

However, according to the laws of probability

\[
P(\text{bank failure per se}) = P(A \text{ and/or } B)
= P(A) + P(B) - P(A \text{ and } B).
\]

10. See footnote 6.
11. \( 6.99^2 = 0.02 \).
The difference between (9) and (10), i.e., \( P(A \text{ and } B) \) represents the probability that a bank failure results from both counterparty default and adverse price movements. This probability is subtracted from the sum of the individual probabilities \( P(A) \) and \( P(B) \) to allow for the possibility that events \( A \) and \( B \) are not mutually exclusive. In this case, event \( A \) and event \( B \) each include those instances where \( A \) and \( B \) occur simultaneously. Subtracting the probability \( P(A \text{ and } B) \) is thus necessary to avoid double-counting.

Only if insolvency due to credit risk and that due to market risk were mutually exclusive events would the guidelines’ method of calculating combined risk not cause double-counting. Mutual exclusion is hardly to be expected, however, since an increase in the volatility of price movements (market risk) also tends to raise the probability that the value of a counterparty’s position crosses his or her insolvency threshold (credit risk), everything else equal. As the guidelines do not consider the possibility of mutually inclusive events, their method of setting capital requirements leads to double-charging in the sense that a bank that just meets the capital charges for credit risk and market risk has a lower chance of failing than a bank that due to the structure of its asset portfolio need only and, in fact, just does meet its capital requirement for credit risk or market risk.

The question of mutual exclusion does not pertain to the issue relating to the degree of correlation between asset returns. The latter issue arises in those instances in which the risk of one asset is treated in isolation of the risks of other assets. This occurs, for example, when applying the RAR formula, since its risk weights are asset-specific. The issue of mutual exclusion, on the other hand, comes up when different kinds of risk are treated in isolation of one another, which is the case with respect to the BIS guidelines’ handling of credit and market risk, or of exchange rate and interest rate risk.

The difference between mutual exclusion and correlation is easily illustrated with the help of equation (10). Mutual exclusion refers to whether the probability \( P(A \text{ and } B) \) equals zero, whereas correlation pertains to how the probability \( P(A \text{ and } B) \) is to be calculated. If \( A \) and \( B \) are uncorrelated or, better said, stochastically independent, then \( P(A \text{ and } B) \) is equal to the product of the two individual probabilities \( P(A) \) and \( P(B) \), but not necessarily to zero. The latter would be the case if \( A \) and \( B \) were mutually exclusive events.

3. AN ALTERNATIVE LIMIT-RISK-BASED PROPOSAL

3.1. Basic Concept

3.1.1. Capital Requirement

The logical solution to the problem that the BIS guidelines do not indicate the bank failure probability that they engender is to design a capital adequacy rule that does. That is the tack we take here. Our approach envisages the supervisory authorities setting a uniform
maximum risk of insolvency for all banks, and banks complying by holding the amount of capital their in-house risk assessment models tell them they must hold in order not to exceed the pre-defined risk limit. As will be seen below, this limit-risk-based approach does not constitute a radical break with the BIS guidelines. Rather, in effect, it merely generalizes and extends the VAR approach as presented in equation (8), while simultaneously eliminating the multiplication factor. However, in contrast to (8), the proposed approach links the capital requirement to the ratio of capital to assets (capital asset ratio [CAR]) instead of to the level of capital.

To develop the approach, we begin with the definition of a bank insolvency. As in (3), insolvency is defined as a situation in which

\[ \text{expenses} - \text{returns} > \text{capital} \quad (11) \]

or equivalently

\[ \text{net income} < -\text{capital} \quad (12) \]

Adding the sum of overhead costs and taxes, which – for the sake of simplicity – we term «overhead», to both sides of (12) yields

\[ \text{net income} + \text{overhead} < -(\text{capital} - \text{overhead}) \quad (13) \]

or equivalently

\[ \text{«returns»} < -(\text{capital} - \text{overhead}). \quad (14) \]

The left-hand side of (14), i.e., «returns» can be viewed as the net income generated from operations with overhead costs and taxes added back in. The addition of overhead and taxes acknowledges the fact that revenue generated to cover these expenses is also subject to risk. At the same time, we deduct these expenses from capital or net worth, since overhead costs and taxes must generally be met before the claims of debt owners can be honored.

Dividing (14) through by total assets \( A \) yields

\[ \frac{\text{ROA}}{\alpha} < -\text{CAR}, \quad (15) \]

where ROA is «returns» divided by \( A \), \( \alpha \) represents «overhead» divided by assets, and CAR symbolizes the capital asset ratio. Hence, according to (15), a bank is insolvent whenever its gross rate of return, minus overhead, falls below its capital asset ratio.\(^\text{12}\)

\(^{12}\) As in footnote 7, we assume that the supervisory authorities close a bank should (15) hold at the end of
Our derivation of the probability of a bank’s failing rests on a single-period perspective. At the beginning of the period the variables on the right-hand side of (15) are taken to be given. The value of ROA, on the other hand, is assumed to be realized at the end of the period. To capture this uncertainty, we treat ROA as a random variable with an expected value \( E(ROA) \) and a standard deviation \( \sigma(ROA) \). The probability that bank \( i \) will be insolvent at the end of the period is thus given by

\[
P(\text{bank failure})_i = P(ROA_i < \alpha_i - C_i) = F_i\left(\frac{\alpha_i - CAR_i - E(ROA_i)}{\sigma(ROA_i)}\right),
\]

where \( F_i \) represents the probability distribution for standardized values of ROA. According to (16), the probability that bank \( i \) will fail depends on (i) the overhead-to-assets ratio \( \alpha_i \), (ii) the capital asset ratio \( CAR_i \), and (iii) the expected value \( E(ROA_i) \) and (iv) standard deviation \( \sigma(ROA_i) \) of the rate of return \( ROA \). Banks with high overhead, a volatile rate of return, a low expected rate of return, and/or a low capital asset ratio are more likely to fail, everything else equal.

To calculate the capital asset ratio consistent with a pre-defined level of insolvency risk \( P^* \) requires solving (16) for \( CAR \), which yields

\[
CAR_i^* = \alpha_i - [E(ROA_i) - F_i^{-1}(P^*) \cdot \sigma(ROA_i)],
\]

where an asterisk signifies a rule-induced value and \( F^{-1} \) symbolizes the inverse function of \( F \).

\( CAR_i^* \) is the capital asset ratio that a bank \( i \) would be required to hold in order to ensure that the probability of its failing does not exceed the uniform\(^{13}\) level \( P^* \) set by the supervisory authorities. According to (17), banks with a high overhead, a volatile rate of return and/or a low expected rate of return would be required to hold a greater share of capital than other banks, everything else equal.

In contrast to the RAR approach, the capital adequacy rule presented in (17) would offer banks various means of meeting their capital requirements. Accordingly, they could lower their overhead and/or alter the composition of their portfolios to achieve higher expected or less volatile rates of return. The RAR approach considers only the volatility of returns.

It is interesting to note that, according to (17), changes in the level of overhead, the expected rate of return, or the latter’s volatility all have an invariant effect on a bank’s required capital asset ratio. Changes in the pre-defined level of insolvency, on the other hand, have a varying influence. The lower the maximum probability of bank failure

\footnote{13. Hence \( P^* \) does not carry a bank-specific index.}
already is, the more a bank's capital asset ratio must increase to induce a further drop in insolvency risk. Figures 3.1 and 3.2 demonstrate this clearly.

**Figure 3.1:**
Required Capital Asset Ratio (based on normal distributed ROA)

![Figure 3.1](image)

**Figure 3.2:**
Required Capital Asset Ratio (based on the CHEBYCHEV Inequality)

![Figure 3.2](image)
Both figures present the capital asset ratios $\text{CAR}^*$ (vertical axis) required to ensure that various hypothetical values for the pre-defined probability $P^*$ (horizontal axis) of bank failure are not exceeded. $\text{CAR}^*$ is calculated according to (17). The values for $\alpha$, $E(\text{ROA})$, and $\sigma(\text{ROA})$, needed to implement (17) are set to 3.6, 4.4 and 1.7 percent, respectively. These figures correspond to the average values for the large majority of banks that operated in Switzerland from 1987 to 1993.\(^{14}\) Figure 3.1 rests on the assumption that ROA is normally distributed, while Figure 3.2 is based on the CHEBYCHEV inequality and thus holds for arbitrarily distributed ROA. Hence, the capital asset ratio required to ensure that the probability of failure does not exceed a given level is higher in Figure 3.2 than in Figure 3.1. For example, to conform to a maximum insolvency risk of 0.1 percent, an average bank in Switzerland would need to display a capital asset ratio of roughly 38 percent according to Figure 3.2 and less than 4.5 percent according to Figure 3.1.

3.1.2. Implied Probability of Contagion

The asserted aim of the BIS guidelines is not only to lessen the chance that a given bank might fail, but also to strengthen the stability of the banking system as a whole, i.e., to lessen systemic risk, or the chances that one bank failure could trigger others (contagion risk). This objective too can be served by a limit-risk-based capital adequacy rule, as the insolvency risk limit $P^*$ also places an upper bound $Q^*$ on the probability of a domino effect.

To see why, observe that a necessary, but not necessarily sufficient condition for contagion is that at least one bank in the industry fail. Under the assumption that the probability of any bank's being the first to fail is independent of some other bank's being the first, the probability $(1 - Q^*)$ that no bank fails in a given period is given by

$$1 - Q^* = (1 - P^*)^I,$$

(18)

where $I$ is equal to the number of banks in the industry. Consequently, the probability $Q^*$ that at least one bank will fail equals\(^{15}\)

$$Q^* = 1 - (1 - P^*)^I.$$

(19)

Under the assumption that at least one bank insolvency is necessary to trigger a chain reaction, equation (19) also corresponds to the probability of contagion. Inasmuch as experience shows that a single bank failure need not set off a chain reaction, $Q^*$ overestimates or, better said, places an upper bound on the level of systemic risk.

\(^{14}\) See Table 4.1 below.

\(^{15}\) This has also been observed by PAROUSH (1988).
Equation (19) indicates that by defining a uniform limit for the probability of a bank failure due to insolvency, the supervisory authorities automatically limit the probability of contagion. The relationship between both probabilities is pictured in Figure 3.3. It is based on the assumption of $I = 450$, which corresponds roughly to the number of banks in our sample that were operating in Switzerland in any given year. As the diagram indicates, the effect of lessening the likelihood of a given bank’s failing on the probability of contagion is non-linear, as was the case with regard to the required capital asset ratio (Figure 3.1 and 3.2). In the present case, decreasing the maximum probability of insolvency lowers the probability of contagion in increasing amounts.

It is somewhat astonishing to observe that even when the maximum allowed probability of insolvency is reduced to 0.1 percent, the probability that at least one bank fails, possibly setting off a domino effect, is still over 35 percent. That observation together with Figure 3.1 and 3.2 implies that banks would need to hold an inordinately large quantity of capital to ensure that no bank fails in any given period.

$Q^*$ places an upper bound on the probability of contagion. In so doing it assumes that any bank, were it to fail, would be equally likely to unleash a chain reaction. In reality, though, one would expect that the failure of a large bank to be more likely to pull down others. Consequently, to lower the risk of contagion it could possibly be more efficient simply to have larger banks hold additional capital rather than to require this of all banks by lowering the uniform insolvency risk $P^*$ accordingly.
3.1.3. Cost and Benefits of Reduced Risk

A limit-risk-based capital adequacy rule has the added advantage of providing a convenient framework in which to analyze the cost and benefits of raising capital standards. The costs of reduced risk within this framework derive from the higher capital asset ratios stricter capital standards call forth. As Figure 3.1 and 3.2 make clear, reducing the maximum probability of insolvency requires banks to hold an increasingly large share of their assets in the form of capital.

According to the MODIGLIANI/MILLER proposition, an increase in the capital asset ratio should have no effect on the weighted average cost of capital. Hence, when viewed from their perspective, a rising capital asset ratio cannot be seen as a sign of increasing cost. But if we assume, as most bankers and regulators seem to believe, that even on a risk-adjusted basis, capital is a more expensive form of funding than non-capital sources, it follows that higher capital standards impose additional costs on banks. In a competitive environment, these added costs will be passed on to customers of banking services and represent social costs of capital requirements. Depending on the demand elasticities, an increase in the social costs of capital requirements will ultimately reduce the size of the banking sector to some degree.

The benefits of higher capital standards, on the other hand, can take two forms in our framework. For one, they can consist of the reduction in systemic risk which a lowering of the maximum risk of insolvency would bring about. As Figure 3.3 indicates, a reduction of the insolvency risk limit lowers the probability of a contagion in increasingly large amounts.

A further benefit arising from lowering the risk of insolvency is the drop in the expected loss \( L \) to the depositors of a bank in case of failure. With respect to a given bank \( i \), the expected loss to the bank’s depositors conditional on the bank’s failing, is defined as

\[
L^* = E(ROA_i \mid ROA_i < \alpha_i - CAR_i) - (\alpha_i - CAR_i)
\]

where \( \alpha \) and \( \text{CAR} \) pertain to the beginning of the period and \( \text{ROA} \) applies to the end.

The term to the right of the inequality sign in (20) represents the insolvency threshold of a bank \( i \). If the bank’s rate of return fell below that level, the bank would be insolvent. In that case, the realized rate of return would not suffice to cover overhead costs and to honor the total claims of debt holders. The expected value appearing in (20) corresponds to the expected rate of return of the bank given that its realized rate of return lies below its insolvency threshold. Since, if a bank failed, depositors would only incur those losses in excess of the insolvency threshold of the bank, the threshold is subtracted from the expected value in (20) to derive the expected loss to depositors conditional on failure.\(^\text{16}\)

In (20), this loss is defined as a fraction of the bank’s assets.

\(^{16}\) Note, as stated above in conjunction with the derivation of (16), that the insolvency threshold \( \alpha \cdot \text{CAR} \)
Calculation of $L^*_i$ necessitates specifying the probability distribution of ROA. Hence, the CHEBYCHEV inequality cannot be applied. Assuming that ROA is normally distributed yields \( L^*_i = \sigma(ROA)_i \cdot [z^* - \lambda^*] \)

\[ \tag{21} \]

where 
\[
\begin{align*}
z^* &= \Phi^{-1}(P^*), \\
\lambda^* &= \phi(-z^*) / \Phi(-z^*), \\
\phi &= \text{standard normal density}, \\
\Phi &= \text{standard normal distribution, and} \\
\ast &= \text{rule-induced value}.
\end{align*}
\]

Equation (21) indicates that, given normally distributed rates of return for banks, the expected loss to depositors of a bank, should the bank fail, depends on the level to which the supervisory authorities set the maximum probability of failure $P^*$ and on the volatility $\sigma(ROA)$ of the rate of return of the bank. Higher volatility and higher insolvency risk lead to higher expected losses to depositors.

**Figure 3.4:**

*Expected Loss Conditional on Failure (based on normally distributed ROA)*

is viewed as given. Hence, whether it is included in the expected value operator or factored out, as in (20), is unimportant. Both specifications are equivalent.

17. The derivation of (21) is based on the formula for the expected value of a truncated normal distribution. See JOHNSON/KOTZ (1970), pp. 81-83.
Figure 3.4 describes the relationship between expected loss and insolvency risk for an assumed standard deviation of the rate of return of .017, the average value in our sample of 479 banks. The same value underlies the curves in Figure 3.1 and 3.2. The expected loss pictured in Figure 3.4 is defined in positive terms (= -L*). As the figure indicates, as in the case of the probability of contagion (Figure 3.3), the benefits accruing to depositors in the form of lower expected loss increase disproportionately to falling insolvency risk. That is, every additional reduction in the probability of insolvency confers increasingly large savings on debt holders in the form of increasingly small expected losses.

To determine the socially «optimal» level of insolvency risk necessitates weighing the social benefits of reduced risk (Figure 3.3 and 3.4) against the social costs of higher prices for financial services (Figure 3.1 and 3.2). The socially «optimal» level of insolvency risk, and the one supervisory authorities should choose, is the one that minimizes the net social cost. This corresponds to the point at which the marginal benefit of reducing the costs of risk and the marginal disbenefit of increasing «production» costs are equal.

Unfortunately, Figures 3.1 - 3.4 cannot be employed for a direct comparison of costs because their vertical axes, with the exception of those in Figure 3.1 and 3.2, refer to different dimensions. The vertical axes in Figure 3.1 and 3.2, for example, pertain to capital asset ratios and not to costs directly, and the vertical axis in Figure 3.3 measures probability and not benefits per se. In fact, only Figure 3.4 is defined in terms of cost or disbenefit.

In principle, the vertical axes in Figure 3.1 and 3.2 could be translated into cost terms if the risk premium that liability owners require to hold the capital of a bank instead of its non-capital liabilities were known. SPREMANN (1994) estimates that the risk premium for Swiss banks amounts to about 5 percent. Multiplying this figure with the capital asset ratios depicted in Figure 3.1 and combining these results with those in Figure 3.4 yield the upper panel in Figure 3.5.19 As the panel shows, the cost of funds decreases with the probability of insolvency, since a higher probability of insolvency implies a lower capital asset ratio according to Figure 3.1. The expected cost of failure to depositors, by contrast, increases. The sum of both effects (i.e., curves) yields the uppermost curve in the panel.

18. Combining Figure 3.2 and Figure 3.4 would be inappropriate since they are based on different assumptions pertaining to the probability distribution of the rate of return.
19. SCHAEFER (1992) defines the social costs and benefits of capital adequacy requirements in a similar fashion, although his approach is somewhat different.
Social Costs of Capital Adequacy (based on normally distributed ROA)

Panel 1

Panel 2

Panel 3
According to the upper panel in Figure 3.5, the socially «optimal» or cost minimizing level of insolvency risk would lie close to zero for the range of risk depicted in the panel. This result depends critically on two assumptions, however: the assumed size of the risk premium and the slope of the two lower curves in the panel.

The effect of the size of the risk premium on our results becomes evident in the second and third panel in Figure 3.5. The second panel assumes the risk premium to be 7 percent, the third panel 10 percent. As can be seen, increasing the risk premium from 5 to first 7 and then 10 percent completely reverses the picture. In the extreme event that the risk premium totals 10 percent (third panel), the socially «optimal» level of insolvency risk lies to the right of 1 percent. And in the case that the risk premium equals 7 percent (middle panel), the socially «optimal» level of insolvency risk is indeterminate as the total cost curve is practically flat.

The flat profile the total cost curve exhibits in the middle panel in Figure 3.5 is due to the fact that the risk premium was set such that both cost curves touch at the far left. As a result, the shape of the total cost curve reflects solely the difference between the absolute values of the slopes of the two lower cost curves. Since the absolute values of their slopes are almost identical, i.e., since the marginal cost of capital is virtually equal to the marginal disbenefit of insolvency, the total cost curve is practically flat.

As equations (17) and (21) indicate, the slopes of the cost curves for capital and for bank failure depend on two factors: the distribution function $F$ of the bank's rate of return and the latter's volatility $\sigma(\text{ROA})$. In other words, the socially «optimal» level of insolvency risk will vary by bank as long as $F$ and $\sigma(\text{ROA})$ differ by bank. In this case, a uniform limit on insolvency risk for all banks will not be socially «optimal». This result may seem to disqualify a limit-risk-based capital adequacy rule. However, varying the risk limit on insolvency (i.e., $P^*$) is not the only means of lowering the social costs of a bank failure.

A deposit insurance scheme could be used to complement a limit-risk-based approach by covering the loss to depositors in the event of a bank failure. A «fair» deposit insurance system would necessitate setting insurance premiums equal to the expected loss to depositors conditional on failure. Figure 3.4 indicates how high these insurance premiums would need to be for different limits on insolvency risk ($P^*$) and for a normally distributed rate of return with a standard deviation of 1.7 percent. Banks with a more volatile rate of return would be required to pay higher premiums under a «fair» deposit insurance scheme.

---

20. This can be shown by differentiating (17) and (21) with respect to the insolvency risk $P^*$.

21. As in the figures before, $\sigma(\text{ROA})$ is set at 1.7 percent in Figure 3.5. That corresponds to the value of $\sigma(\text{ROA})$ for an average bank in our sample.
3.1.4. Multi-Period Perspective

The analysis up to this point has concentrated on a single time period. The probability of insolvency studied here has referred to the chances of a bank’s failing at the end of a period, given its overhead and capital asset ratio at the beginning of the period and the expected value and volatility of its rate of return over the period. It might seem that results pertaining to a single time frame may not hold up when a sequence of periods are considered. Specifically, it could appear that a loss that pushes a bank to (but not over) the brink of insolvency in one period increases the chances of the bank’s failing in the future under a limit-risk-based capital adequacy scheme. However, this suspicion is false if:

- a bank’s rates of return are independently and identically distributed (i.i.d.) over time (random walk hypothesis),
- bank capital stems solely from retained earnings, and
- the level of non-capital liabilities remains constant.

To see how this could be, observe that the last condition implies that

$$A_{t+T} - C_{t+T} = A_t - C_t.$$  

That is, a bank’s level of non-capital liabilities at date \(t + T\) and at date \(t\) are equal. Furthermore, retaining a fixed share \(\gamma\) of returns implies that

$$A_{t+T} = A_t \cdot \prod_{\tau=1}^{T} (1 + \gamma \cdot \text{ROA}_{t+\tau}).$$  

i.e., that the bank’s assets at date \(t + T\) are equal to their level at date \(t\) times the cumulative retained rate of return over \(T\) time periods.

Dividing (22) through by \(A_{t+T}\), replacing the latter by (23), and taking logs yield

$$\ln(1 - \text{CAR}_{t+T}) = \ln(1 - \text{CAR}_t) - \sum_{\tau=1}^{T} \ln(1 + \gamma \cdot \text{ROA}_{t+\tau}).$$  

For low values of \(\text{CAR}\) and \(\gamma \cdot \text{ROA}\) the following relationship holds approximately:

$$\text{CAR}_{t+T} = \text{CAR}_t + \sum_{\tau=1}^{T} \gamma \cdot \text{ROA}_{t+\tau}.$$  

\(25\)
When \( \text{CAR}_{t+T} \) exceeds 10 percent this relationship breaks down. Hence, it only provides a good approximation for a short sequence of periods.

The bank fails at an arbitrary date \( t + T \) if

\[
\gamma \cdot \text{ROA}_{t+T} < \alpha - \text{CAR}_{t+T-1}.
\]

(26)

The overhead-to-assets ratio \( \alpha \) is treated as a constant, and \( \text{CAR}_t \) is given at time \( t \). Hence, the probability that the bank will fail at time \( t + T \), based on (25), is

\[
P \left( \sum_{t=1}^{T} \gamma \cdot \text{ROA}_{t+T} < \alpha - \text{CAR}_t \right),
\]

(27)

where

\[
E \left( \sum_{t=1}^{T} \gamma \cdot \text{ROA}_{t+T} \right) = T \cdot \gamma \cdot E(\text{ROA}) \text{ and }
\]

\[
\sigma \left( \sum_{t=1}^{T} \gamma \cdot \text{ROA}_{t+T} \right) = T^{\frac{3}{2}} \cdot \gamma \cdot \sigma(\text{ROA}).
\]

Since the expected value of the cumulative rate of return increases faster than the latter’s volatility as the process evolves through time, the probability that the bank will fail actually falls as \( T \) increases. Moreover, as long as the bank meets its capital requirement \( \text{CAR}_t^* \) at time \( t \), i.e., \( \text{CAR}_t \geq \text{CAR}_t^* \), it will have no problem doing so in the future.

Agreed, the results hold under the conditions stipulated above. Particularly restrictive is the assumption that ROA is i.i.d., which implies that the expected value and volatility of ROA are constant through time. Nevertheless, the result is capable of demonstrating that a low or negative rate of return in one period does not necessarily lower a bank’s chances of surviving in the future. Whether a given bank actually does survive depends, of course, on whether (15) ever eventuates.

22. We assume that \( E(\text{ROA}) > 0 \).
3.2. Practical Implementation

In order to apply a limit-risk-based capital adequacy rule to a bank, the distribution function, the level of overhead costs, and the expected value and volatility of the bank’s rate of return must be known. Equation (17) makes this clear.

Although some of the inputs may be difficult to estimate, calculating the expected value and the volatility of a portfolio of bank-held assets is, in principle, a straightforward application of a few simple rules for manipulating expected values. According to these principles

\[ E(\text{ROA}_i) = x_i' \mathbb{E}(\text{ROA})_i \]  

\[ \sigma(\text{ROA}_i) = (x_i' \Sigma x_i)^{1/2} \]  

where \( x_i \) = column vector of the asset proportions of bank \( i \),
\( E(\text{ROA})_i \) = column vector of the expected rates of return of the assets in \( x_i \),
and
\( \Sigma_i \) = variance-covariance matrix of the rates of return of \( x_i \).

For a bank to apply (28) and (29) it would need to subdivide its on and off-balance-sheet assets into subgroups of assets whose rates of return follow a common probability distribution, i.e., have roughly identical expected values and volatility. Natural candidates for a common subgroup would be assets whose rates of return are driven in roughly equal manner by common factors, e.g., loans to the same industry of similar quality and duration.

The next step in implementing (28) and (29) would be to compute time series of the returns, or relative changes (ROA) in the aggregate value of the assets of a common subgroup. In contrast to the BIS guidelines, the returns should reflect the effects of both default risk and market risk to avoid the double-counting implicit in the BIS approach.

A question which arises at this point is whether to employ the book or market value of assets. From the standpoint of insolvency, actually neither measure is ideal. What is required is the liquidation value of a bank’s assets. True, if the insolvency of a bank were determined solely by supervisory authorities on the basis of book values, a case could be made for the use of book values inasmuch as in this event book values alone would determine the probability of insolvency. However, book values provide a poor basis for assessing the expected loss to debt holders conditional on insolvency (equation [21]), because the expected loss depends on the value of bank assets at the moment of liquidation.

Indeed, the liquidation event itself will probably affect the value of a bank’s assets. That is why market values too are less than an ideal basis for assessing the liquidation

\[ \text{Non-capital liabilities would represent assets with negative returns under this scheme.} \]
value of a bank. Moreover, evidence presented by Keeley (1990, p. 1185) for the US shows that changes in the market value of banks' assets tend to lag behind changes in their book values. That would suggest that market values merely project the implications of current book value changes into future income streams, leading, as a result, to «excess» volatility in market values.

To be sure, readily tradable assets should be marked to market since, in this case, the current market prices of assets probably do correspond to their liquidation values. With respect to non-traded assets (e.g., non-securitized loans), the best approximation probably would consist of calculating the cash values of the assets future payment streams based on current interest rates (market risk) and past rates of default (credit risk).

Given time series for the values of asset categories, it is, in principle, a simple matter to calculate the expected rates of return $E(\text{ROA})$ of the various asset groups and their variance-covariance matrix $\Sigma$, that appear in (28) and (29). The number of calculations required could prove to be quite large, however, as these increase geometrically with the number of asset groups differentiated. Specifically, a variance-covariance matrix pertaining to the returns of $J$ assets would necessitate calculating $J(J + 1)/2$ unique values. Of course the amount of computing could be greatly reduced if the $J(J - 1)/2$ unique covariances in $\Sigma$ and their associated portfolio effects were ignored, possibly based on the fear that portfolio effects will break down anyway in a financial crisis. In the event that covariances were ignored, equation (5), appropriately rewritten for ROA, would replace equation (29).

The final step in calculating the expected value and the volatility of a bank's rate of return involves inserting the results for $E(\text{ROA})$ and $\Sigma$ in (28) and (29), employing current values for $x$. In effect, applying (28) and (29) results in an aggregation of the expected values and volatilities of the rates of return of the various asset categories of a bank. Viewed from this angle, the procedure just described may seem unnecessarily involved. Why not simply calculate the expected value and volatility of the aggregate rate of return of a bank directly? Two reasons advise against this.

For one, a capital requirement scheme that does not accurately discriminate between the relative risk of different activities invites banks to improve performance while ignoring risk. According to portfolio theory a principal source of portfolio volatility is portfolio composition ($x$). Hence, to avoid risk-seeking behavior it is important to link a capital adequacy rule to the structure of a bank's portfolio of assets.

Another reason for adopting the multi-stage approach is that it provides a basis for improving the mean-variance efficiency of a bank's portfolio. According to an important principle of finance theory, a portfolio of assets is not mean-variance efficient unless all assets with the same marginal variance have identical expected returns.\footnote{An excellent exposition of the derivation of this principle can be found in Berndt (1991, chapter 2).} The marginal variance of an asset measures its marginal contribution to the total portfolio variance. The marginal variance of each asset in a portfolio makes up the elements in vector $2\Sigma x$, which results from differentiating (29) with respect to $x$, the composition of the portfolio.
Hence, the inputs $\Sigma$ and $E(ROA)$, used to compute (28) and (29), could provide banks with a means for improving expected returns without increasing risk. This offers banks the opportunity of raising the mean-variance efficiency of their portfolios while decreasing their capital requirements in a manner commensurate with the objectives of the BIS guidelines.

A major problem plaguing any risk-based capital adequacy rule is that the probability distributions of asset returns are often not stable in the sense that their expected values and standard deviations (volatility) shift through time. As a result, the set of historical observations used to calculate the vector $E(ROA)$ and the matrix $\Sigma$ used in (28) and (29) may not be representative of the current situation. There are basically two solutions to the problem. Either one limits the calculation of $E(ROA)$ and $\Sigma$ to «crisis» periods thereby setting an upper limit on these parameters, or one attempts to estimate and then to control for the effects of a changing economic environment on the two inputs. Each approach has its pros and cons. The first method is easy to implement but less precise, while the second approach is hard to implement but more exact.

In order to implement a limit-risk-based capital adequacy rule, the probability distribution $F$ of the aggregate rate of return of a bank must also be known. If the rates of return of the individual asset categories of a bank are normally distributed then their aggregate rate of return will also follow a normal distribution. However, this does not generally hold for other probability distributions. Hence, unless the probability distribution of the aggregate rate of return of a bank is known, it is safer to employ the Chebychev inequality, which holds for an arbitrary probability distribution.

The implementation of a limit-risk-based capital adequacy rule is akin to allowing banks to use their own in-house models to assess risk, a procedure which the 1995 Supplement regarding market risk foresees. With respect to the use of proprietary risk assessment models the 1995 Supplement lists a set of qualitative and quantitative criteria which a bank’s in-house model would be expected to fulfill. These pertain basically to the role such models should play in the management of a bank (qualitative criteria) and to the degree of precision these models should exhibit (quantitative criteria). In general, these same criteria would need to apply under a limit-risk-based capital adequacy scheme.

4. **EMPIRICAL APPLICATION TO BANKS IN SWITZERLAND**

4.1. *Data Base and Procedure*

In the following, the concepts of a limit-risk-based capital adequacy scheme will be applied to 479, or the great majority of banks that operated in Switzerland for at least three years during the period 1987-93\textsuperscript{25}. The aim of the investigation is threefold:

\textsuperscript{25} Private banks, finance companies, credit co-operatives, and branches of foreign banks are not considered.
To examine the extent to which current Swiss capital adequacy rules, although by design unintended, nevertheless appear to impose a uniform upper limit on insolvency risk. (Section 4.2.1)

To investigate the degree to which Swiss banks could currently meet a limit-risk-based capital requirement. (Section 4.2.2)

To estimate what the expected loss to depositors would be, conditional on bank default, were these banks to meet a limit-risk-based capital requirement. (Section 4.2.3)

The data base consists of the annual balance sheet and income statements from the banks in our sample. Over 3000 accounting statements were examined in total. Data drawn from these sources were used to calculate the insolvency risk (equation [16]), the limit-risk-based capital asset ratio (equation [17]), and the expected loss to depositors, conditional on bank failure (equation [21]) for each bank. Returns, as described in (13) and (14), are defined here as the total operating revenues of a bank, net of interest expenses, commission fees, and loan loss provisions. Overhead represents taxes and expenses on labour, materials, and office space. Capital corresponds roughly to Tier 1 funds and encompasses bank capital and published reserves. Assets are equal to total on-balance-sheet assets. The ROA refer to annual rates of return.

The multi-stage procedure described in section 3.2 for calculating $E(\text{ROA})$ and $\sigma(\text{ROA})$, which enter as inputs into the above equations, is not employed. Instead it is assumed that the portfolio structure $x$ of a bank remained constant over the period of observation. In this case, (28) and (29) constitute identities.

Accounting data are obviously not an ideal basis for applying capital adequacy rules. For one, accounting rules serve other purposes. However, the data used cover a particularly turbulent period in Swiss banking in which roughly a fifth of the banks and finance institutions exited the industry as a result of liquidation, takeover, merger, or cessation of business (SBA, 1993). One would expect that not even accounting data could hide this turbulence completely.

The Swiss National Bank groups the banks studied here into eight different categories: large universal banks, investment banks ($Börsenbanken$), commercial banks ($Handelsbanken$), foreign-controlled banks, cantonal banks, regional banks, consumer credit banks, and other banks. The banks in these groups differ in size and in the structure of their balance sheets.

The largest banks are large universal banks, as the name implies, with an average balance sheet total of SFr. 127 billion over the period covered, followed by cantonal banks (SFr. 7.5 billion), commercial banks (SFr. 2.1 billion) and foreign-controlled banks (SFr. 0.7 billion). Regional banks, consumer credit banks (SFr. 0.5 billion, 26. The data were supplied by the Swiss National Bank with the consent of the banks affected. We extend our thanks to these institutions for their kind help.
respectively), investment banks (SFr. 0.3 billion) and other banks (SFr. 0.2 billion) are small by comparison.

According to the HERFINDAHL index, the assets of the cantonal banks, regional banks, and consumer credit banks are most narrowly diversified. Cantonal and regional banks specialize in mortgage loans and loans to public-sector entities. Between 69 (cantonal banks) and 77 percent (regional banks) of their assets fall into these two categories. Consumer credit banks, on the other hand, specialize in unsecured loans, with roughly 76 percent of their assets belonging to this group.

The sources of funds too vary across these three bank groups. The capital asset ratio of the cantonal banks and regional banks are the lowest in the industry, standing at 4.1 and 5.2 percent, respectively (see below Table 4.1). The capital asset ratio of consumer credit banks do not lie much higher, averaging 9.1 percent. The structure of the non-capital liabilities of the three bank groups differs by more. Cantonal banks exhibit relative broad non-capital financing, with an emphasis on savings-deposit funding. Roughly a third of their non-capital liabilities stem from this source. In the case of regional banks the share is even higher at 43 percent. Consumer credit banks, on the other hand, draw the largest share of their non-capital liabilities from certificates of deposit (52 percent).

Large banks, commercial banks, investment banks, and foreign-controlled banks exhibit a relative broad asset structure. Moreover, in the case of commercial banks, investment banks, and foreign-controlled banks, their asset structures too are similar. All three have relative large shares of cash and deposits with other banks, ranging from roughly 30 (commercial banks) to approximately 43 percent (foreign-controlled banks) of total assets, which attest to the high degree of liquidity of these banks. Shares, too, carry a relatively heavy weight in the case of foreign-controlled banks, investment banks, and commercial banks, with the latter two groups also exhibiting comparatively large real-estate holdings. By contrast, the asset portfolios of large universal banks display a heavier leaning towards non-secured loans, mortgage loans, and money market instruments.

The structure of funding also differs among these four bank groups. Investment banks, foreign-controlled banks, and commercial banks exhibit high capital asset ratios, ranging from 16.5 to 28.5 percent (Table 4.1), whereas in the case of large banks they average about 6 percent. On the other hand, the non-capital financing in all four bank categories is similarly short-term. Particularly foreign-controlled banks, but then too, commercial banks acquire a good share of their non-capital funds from other banks in the form of time deposits, while investment banks and large banks resort more to time deposits (large banks) and demand deposits (investment banks) from non-banks, although commercial banks, too, depend in large measure on non-bank demand deposits.

According to portfolio theory, the different balance sheet structures of banks of different categories imply that the expected value and volatility of their aggregate rates of return will vary. This is borne out by the results that follow.
4.2. Results

4.2.1. Insolvency Risk

We first view the results pertaining to the probability that a bank fails (Table 4.1). According to equation (16), the risk of insolvency depends on four factors: overhead costs, the capital asset ratio CAR, the expected rate of return $E(ROA)$, and the standard deviation of the rate of return $\sigma(ROA)$. Hence, banks with high overhead, a low capital asset ratio, a low expected rate of return, and/or a volatile rate of return carry a relative high risk of insolvency, everything else equal.

The values\textsuperscript{27} for these variables as they appear in Table 4.1 present a mixed picture. Cantonal banks, large universal banks, and regional banks exhibit low capital asset ratios and low expected rates of return on average, implying a high probability of default. Yet with the possible exception of regional banks, firms belonging to these categories carry low overhead and have less volatile rates of return, which suggest a low risk of insolvency. The opposite holds true for investment banks and foreign-controlled banks: capital asset ratios and expected rates of return are high, but so are overhead and the volatility of the rates of return.

Due to the conflicting evidence it is not self-evident which category of banks carries a higher probability of insolvency. As it turns out, regional banks exhibited the greatest insolvency risk over the period of observation, whether one assumes normally distributed («Norm.») rates of return or relies on the CHEBYCHEV inequality («Cheb.»). This result could lead one to believe that the capital asset ratio of a bank and its expected rate of return are the driving forces behind the probability of failure, since regional banks do poorly on both accounts. Yet investment banks, whose capital asset ratios and expected rates of return are among the highest, display the second highest probability to fail from one year to the next, whereas large universal banks, which score poorly on both measures, appear to be the safest banks.

\textsuperscript{27} The values appearing in the following tables represent averages of the corresponding figures calculated at the level of individual banks. Since many of the bank-specific figures are based on formulas containing non-linearities, one should not expect the averages in the tables to fit equations (16), (17) and (21).
In short, no single factor alone can explain the probability of insolvency. Consequently, any capital adequacy rule, such as the RAR approach, that is based on just one determining factor of insolvency risk (in the case of RAR: volatility) is not likely to be effective in strengthening the soundness of banks. The capital adequacy guidelines for Swiss banks, which are based on the RAR approach, seem particularly ineffectual. The rank correlation coefficient between the capital asset ratio of banks in Switzerland and their probability of default is positive, statistically significant, and equal to 0.194, implying that the banks with the highest capital asset ratios are those most likely to fail. The relationship is obviously not tight, but it nevertheless shows that the insolvency risk of Swiss banks is far from uniform, despite the fact that – with the possible exception of cantonal banks – the same capital requirements apply to all banks. In fact, under the assumption that the rank order of the banks’ effective capital asset ratios CAR does not generally differ from the rank order required ratios CAR* would generate, the positive correlation between CAR and insolvency risk suggests that current capital requirements in Switzerland overcharge low-risk banks and undercharge high-risk banks.

4.2.2. Capital Requirements

In this section we turn the question of the last section around. Instead of calculating the insolvency risk which the effective capital asset ratio of a bank implies, we assume two different insolvency risk limits, 1 percent and 0.1 percent, and investigate to what extent the effective capital asset ratios of banks in Switzerland would have sufficed to meet these risk limits during the period of observation. The results appear in Table 4.2.

According to equation (17), upon which Table 4.2 is based, the banks most likely to meet a limit-risk-based capital adequacy requirement are those with low overhead and a high expected and non-volatile rate of return. Good candidates by these measures are
large universal banks, cantonal banks, and consumer credit banks, since each bank category scores well on at least two of these measures. Large universal banks and cantonal banks carry low overhead and their rates of return are not volatile, while consumer credit banks have high expected rates of return with low volatility.

Banks unlikely to meet a limit-risk-based capital adequacy rule, on the other hand, are investment banks and foreign-controlled banks as they are weak on two scores. They exhibit high overhead and their rates of return are volatile.

Table 4.2: Comparison of Actual (CAR) and Required (CAR*) Capital Asset Ratios

<table>
<thead>
<tr>
<th>BANKS</th>
<th>CASES</th>
<th>OVERHEAD</th>
<th>E(ROA)</th>
<th>σ(ROA)</th>
<th>CAR</th>
<th>CAR*</th>
<th>CAR*</th>
<th>CAR*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cantonal</td>
<td>30</td>
<td>0.009</td>
<td>0.012</td>
<td>0.002</td>
<td>0.041</td>
<td>0.008</td>
<td>0.000</td>
<td>0.032</td>
</tr>
<tr>
<td>Large</td>
<td>4</td>
<td>0.017</td>
<td>0.023</td>
<td>0.003</td>
<td>0.060</td>
<td>0.013</td>
<td>0.000</td>
<td>0.053</td>
</tr>
<tr>
<td>Regional</td>
<td>212</td>
<td>0.009</td>
<td>0.008</td>
<td>0.013</td>
<td>0.052</td>
<td>0.092</td>
<td>0.032</td>
<td>0.288</td>
</tr>
<tr>
<td>Commercial</td>
<td>22</td>
<td>0.035</td>
<td>0.041</td>
<td>0.016</td>
<td>0.165</td>
<td>0.109</td>
<td>0.032</td>
<td>0.356</td>
</tr>
<tr>
<td>Investment</td>
<td>58</td>
<td>0.095</td>
<td>0.129</td>
<td>0.032</td>
<td>0.285</td>
<td>0.191</td>
<td>0.040</td>
<td>0.676</td>
</tr>
<tr>
<td>Consumer Credit</td>
<td>11</td>
<td>0.045</td>
<td>0.055</td>
<td>0.009</td>
<td>0.091</td>
<td>0.056</td>
<td>0.012</td>
<td>0.197</td>
</tr>
<tr>
<td>Foreign-Controlled</td>
<td>138</td>
<td>0.058</td>
<td>0.071</td>
<td>0.020</td>
<td>0.227</td>
<td>0.130</td>
<td>0.034</td>
<td>0.439</td>
</tr>
<tr>
<td>Other</td>
<td>4</td>
<td>0.020</td>
<td>0.035</td>
<td>0.013</td>
<td>0.210</td>
<td>0.079</td>
<td>0.016</td>
<td>0.284</td>
</tr>
<tr>
<td>Total</td>
<td>479</td>
<td>0.036</td>
<td>0.044</td>
<td>0.017</td>
<td>0.137</td>
<td>0.109</td>
<td>0.030</td>
<td>0.362</td>
</tr>
</tbody>
</table>

The empirical results in Table 4.2 bear out our expectations inasmuch as large universal banks and cantonal banks would have to hold the smallest, and the investment banks and foreign-controlled banks the largest share of capital under a limit-risk-based capital adequacy rule, irrespective of the risk limit (1 percent or 0.1 percent) and of whether the CHEBYCHEV inequality or a normal distribution were applied.

Nonetheless, the regional banks would have the toughest time meeting a limit-risk-based capital adequacy requirement. This is principally due, on the one hand, to their low and relatively volatile rates of return, which result in high capital needs, and, on the other hand, to the modest capital asset ratios actually exhibited by these banks. For the same reason, only regional banks could not fulfill a limit-risk-based capital adequacy requirement if the insolvency risk limit were set at 1 percent and no distribution assumption made.

On the other hand, only large universal banks and cantonal banks could meet a 0.1 percent risk limit, based on the CHEBYCHEV inequality. Otherwise, under the assumption of normally distributed ROA, banks of all categories could generally fulfill either risk limit.
4.2.3. Expected Loss to Depositors Conditional on Insolvency

Were a risk limit met, the question then arises as to the loss depositors could expect to suffer should their bank nevertheless fail. Table 4.3 provides answers to this question. As equation (21), the basis of Table 4.3, indicates, the only factor that causes the expected loss to depositors to vary across banks, given that the banks’ rates of return are normally distributed, is the volatility of the rate of return. Hence those banks with the most volatile rates of return will expose their depositors to the greatest potential loss under a limit-risk-based capital adequacy scheme. Table 4.3 indicates these to be investment banks, foreign-controlled banks, and commercial banks. By contrast, cantonal banks and large universal banks subject their clientele the least to risk exposure.

As was pointed out in section 3.1.3, a deposit insurance scheme could be set up to guard against this residual chance of loss. In that case, the negative values of the expected loss to depositors appearing in the last two columns of Table 4.3 would represent «fair» insurance premiums for the two default risk limits considered.

Table 4.3.: Expected Loss Conditional on Bank Insolvency (based on normally distributed ROA)

<table>
<thead>
<tr>
<th>BANKS</th>
<th>CASES</th>
<th>σ(ROA)</th>
<th>P* = 1%</th>
<th>L*</th>
<th>P* = 0.1%</th>
<th>L*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cantonal</td>
<td>30</td>
<td>0.002</td>
<td>-0.001</td>
<td>-0.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large</td>
<td>4</td>
<td>0.003</td>
<td>-0.001</td>
<td>-0.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regional</td>
<td>212</td>
<td>0.013</td>
<td>-0.004</td>
<td>-0.004</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commercial</td>
<td>22</td>
<td>0.016</td>
<td>-0.006</td>
<td>-0.005</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Investment</td>
<td>58</td>
<td>0.032</td>
<td>-0.011</td>
<td>-0.009</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consumer Credit</td>
<td>11</td>
<td>0.009</td>
<td>-0.003</td>
<td>-0.003</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foreign-Controlled</td>
<td>138</td>
<td>0.020</td>
<td>-0.007</td>
<td>-0.006</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>4</td>
<td>0.013</td>
<td>-0.005</td>
<td>-0.004</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>479</td>
<td>0.017</td>
<td>-0.006</td>
<td>-0.005</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

FAI

5. SUMMARY AND CONCLUSION

The 1988 Basle Accord and the 1995 follow-up Supplement have brought an improvement to capital adequacy regulation inasmuch as they give greater weight to risk assessment. Yet ironically, the capital adequacy guidelines laid down in both studies provide, by design, little indication of the level of soundness their implementation imparts to banking. This is an obvious handicap for supervisory authorities dedicated to strengthening the soundness and stability of banking systems.
This paper has presented an alternative, yet by no means radically new approach to capital adequacy regulation. The approach envisages bank supervisory authorities setting a maximum risk of insolvency which banks would not be allowed to exceed, and an individual bank complying by maintaining a capital-to-asset ratio commensurate with the pre-defined insolvency risk limit, the bank’s overhead costs, and with the expected value and volatility of its rate of return.

The limit-risk-based capital adequacy rule presented in this paper offers a number of advantages.

- It avoids double counting risk because – unlike the BIS guidelines – it does not distinguish between kinds of risks but solely between types of assets.
- It sets a uniform upper limit on the insolvency probability of a bank, providing supervisory authorities with a basis for assessing the level of soundness their capital standards could achieve.
- It places an upper bound on the level of systemic risk, indicating to supervisory authorities to what extent capital requirements strengthen the soundness of a banking system as a whole.
- It provides a convenient framework for assessing the costs and benefits increased capital standards entail.
- It creates incentives and the needed instruments for banks to improve their mean-variance efficiency.

Application of concepts stemming from a limit-risk-based capital adequacy rule to banks operating in Switzerland from 1987 to 1993 yielded the following results.

- The current capital requirements for banks in Switzerland do not appear to impose a uniform insolvency risk limit on Swiss banks. In fact, banks with high capital asset ratios tend to display an above average default risk, implying that current capital requirements tend to overcharge low-risk banks and to undercharge high-risk ones.
- Most banks in Switzerland could meet a limit-risk-based capital adequacy standard under the assumption of normally distributed bank rates of return, even if the risk limit were set as low as 0.1 percent. However, if arbitrarily distributed rates of return are assumed, few banks could meet a 0.1 percent risk limit.
- The average loss depositors of a bank could expect to incur under a limit-risk scheme in the event that their bank were to fail ranges from 0.6 (limit risk = 1 percent) to 0.5 percent (limit risk = 0.1 percent) of the bank’s total assets.

It goes without saying that the introduction of a limit-risk-based capital adequacy scheme still poses a number of problems. Questions pertaining to the qualitative and quantitative criteria that the 1995 Supplement requires risk assessment models to meet, have barely been touched upon in this paper. In addition, the special problems connected to options have been ignored. Nonetheless, it is fair to say that if the «value-at-risk» methodology

28. Note, however, that the large majority of recent bank crises in, e.g., the US, Scandinavia, or Japan have
is viewed as a viable approach to capital adequacy regulation, then the same must hold true for a limit-risk scheme. The gains from implementing such a scheme seem self-evident.

LITERATURE


stemmed from «traditional banking activities rather than new instruments» (Hellwig, 1995). Hence, this omission may be less serious than it at first appears.

29. For a skeptical view see KUPIEC/O'BRIEN (1995).
SUMMARY

The paper presents an alternative to the capital adequacy requirements proposed by the Basle Committee on Banking Supervision. Akin to the value-at-risk method, the alternative approach envisages national supervisory authorities setting a maximum risk of insolvency that no bank would be allowed to exceed, and each bank complying by holding a capital-to-asset ratio commensurate with its overhead costs and with the expected value and volatility of its rate of return. The alternative approach offers a number of advantages, including a framework for assessing the costs and benefits that increasing capital standards entails. The paper discusses problems of implementation and applies the approach to data taken from the great majority of banks that operated in Switzerland in the period 1987-93. The results suggest, among other things, that current capital requirements in Switzerland tend to overcharge low-risk banks and to undercharge high-risk ones.

ZUSAMMENFASSUNG