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THE RELATIONSHIP BETWEEN RISK AND CAPITAL IN SWISS COMMERCIAL BANKS: A PANEL STUDY*

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The Relationship Between Risk and Capital in Swiss Commercial Banks: A Panel Study*

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Abstract

In this paper we investigate the relationship between changes in risk and changes in leverage for a panel of Swiss banks. Using market data for risk and both accounting and market data for capital over the period between 1990 and 2002, we find a positive correlation between changes in capital and changes in risk, i.e., higher levels of capital are associated with higher levels of risk. Despite this positive correlation, however, we do not find a significant relationship between the default probability and the capital ratio.

Keywords: Leverage ratios, bank capital, risk taking.

JEL Classification Numbers: G21, G28

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1 Introduction

Since the Basel Accord of 1988, capital adequacy rules have been the focus of international banking regulation. Despite the prominent role of such rules in prudential regulation, however, the knowledge about the relationship between banks' capital and their risk-taking behavior is still very limited – both theoretically and empirically. In this paper we try to contribute to this knowledge by providing empirical evidence for Swiss banks.

The lack of understanding about the relationship between capital and risk is most obvious in the context of capital adequacy requirements. It is largely undisputed that, everything else being constant, a bank's probability of default decreases with the level of capital – a simple buffer stock effect. Disagreement, however, exists about the indirect incentive effects originating from the level of (required) capital. On the one hand, some people argue that capital represents the stake a bank has to lose in case of insolvency. Therefore, the bank has an incentive to incur lower risks the higher the amount of capital – similar to deductibles in insurance policies. This incentive effect reinforces the buffer effect, and banks' stability increases with their level of capital. On the other hand, it is argued that capital is very costly. In order to generate an adequate return on equity, banks have to incur higher risks to receive higher risk premia on their investments the higher the level of capital. The net effect of this negative incentive effect and the buffer effect is ambiguous. It is possible that the default risk increases as the level of capital is increased.[1]

With theory not providing any clear answers, the empirical evidence on the relationship between leverage and the riskiness of banks does not offer conclusive results, either.[2] In most studies the sign and the magnitude of the results strongly depend on both the measure of risk and the sample considered.[3] At best, there are weak

[1] For some of the various theoretical arguments concerning the effect of capital regulation on risk taking, see, for instance, Koehn and Santomero (1980), Furlong and Keeley (1989), Rochet (1992), and Blum (1999).

[2] Also see the Bank for International Settlements (1999) survey of the theoretical and empirical literature on the effects of capital requirements.

[3] See, e.g., Shrieves and Dahl (1992), Aggarwal and Jacques (1998), and Hovakimian and Kane (2000).

indications that the likelihood of failure tends to decrease with the capital ratio of a bank.[4]

In addition to these apparent deficits, our work is further motivated by two observations. First, the growing concern about the increasing complexity and about the effectiveness of the current risk-weighting approach to capital regulation has led many to favor simple leverage restrictions. Acknowledging that there are problems with any risk-weighting scheme (most importantly so-called 'regulatory arbitrage'), a more moderate proposal is to supplement the current system with additional leverage restrictions. While such a combination of risk-weighted and unweighted capital requirements is already in effect in the United States, most countries exclusively rely on risk-weighted rules at present. Obviously, for all proposals involving simple leverage ratios, the relationship between (unweighted) capital and banks' riskiness is of central importance. Second, almost all of the available evidence on the relationship between risk and capital is based on data from the United States. In order to be able to judge whether it might be useful to introduce leverage restrictions internationally, more evidence from other banking systems is necessary.

Using monthly data covering a period of 10 years between 1990 and 2002 for a sample of 19 publicly traded Swiss banks, we examine the relationship between the leverage ratio and the risk of banks. We find a positive correlation between changes in capital and risk. Based on market data for assets, an increase in the capital ratio of 1 percent is associated with an increase of 1.2 percent in volatility of the banks' assets on average. In spite of the positive relationship between risk and capital, we do not find a significant relationship between the likelihood of failure of a bank and its capital ratio.

The paper is organized as follows. In section 2, we present the empirical design of our study. In section 3 we develop our measure of risk, and in section 4 an indicator of the default probability is derived. Section 5 describes the data, and the results of our estimations are presented in section 6. The final section discusses some limitations.

[4] For instance, Thomson (1991) and Estrella (2000). Their results, however, are sensitive in particular with respect to the time horizon under consideration.

2 Empirical Design

We estimate the following relationships:

$$\Delta\sigma_{A_{i,t}} = \alpha_{0,i} + \alpha_1 \Delta c_{i,t} + \alpha_2 \Delta\sigma_{BSI_t} + u_{i,t} \tag{1}$$

and

$$\Delta z_{i,t} = \beta_{0,i} + \beta_1 \Delta c_{i,t} + \beta_2 \Delta\sigma_{BSI_t} + v_{i,t}, \tag{2}$$

where $\sigma_{A_{i,t}}$ is the volatility per unit of market value of assets, $c_{i,t}$ is the capital ratio for bank i at time t, σ_{BSI_t} is the volatility of the Swiss bank stock index at time t and $z_{i,t}$ is an indicator of the likelihood of failure of bank i. This indicator will be derived in section 4. We assume that the unobservable terms $u_{i,t}$ and $v_{i,t}$ are i.i.d. normally distributed with zero mean and heteroscedastic variances $\sigma^2_{u,i}$ and $\sigma^2_{v,i}$, respectively.

Our specification is similar to the one adopted by Hovakimian and Kane (2000) who estimate (i) the changes in the leverage ratio as well as (ii) the changes in the fair deposit insurance premium per dollar of deposits – which is monotonically related to the likelihood of default that we use – as a function of changes in the riskiness of banks' assets.

In our analysis we will focus on α_1 and β_1, the coefficients of the simple unweighted capital ratio in equations (1) and (2). A positive value for α_1 implies that improvements of banks' capitalization tend to be correlated with increased riskiness. Such a correlation may reflect either regulatory pressure – through the risk-based capital requirements – and/or some form of market pressure, or banks' objective functions. A negative value for β_1 would imply that improvements in capitalization tend to be correlated with decreases in the likelihood of default. As mentioned in the introduction, the capital ratio of a bank affects its likelihood of failure through two channels. The first one is a direct buffer effect. More capital implies a bigger cushion to absorb an adverse shock and hence reduces the likelihood of failure. The second channel concerns the correlation between capitalization and risk as reflected by (1). The net effect of changes in the capital ratio on the probability of failure is therefore a priori ambiguous.

The parameters α_2 and β_2 account for the systemic component of variations in the riskiness and the likelihood of failure of bank i.

3 Measure of Risk

The market value of a bank's assets A and, hence, the volatility of these assets $\sigma_A A$ are not directly observable. Following Merton (1974)[5], we estimate the unobserved market value and risk of a bank's portfolio by modeling the bank's equity as a call option on the value of the assets of the bank.

Due to the limited liability of shareholders the value of equity at time T, the maturity of the debt, is

$$\max\left[0, A^T - D^T\right],$$

where A^T and D^T are the asset value and the book value of liabilities at time T, respectively. This corresponds to the value of a standard call option at maturity, where the level of debt D^T is the exercise price of the option. This analogy allows us to interpret a bank's equity as a call option on the bank's assets.

Since we do not have data on interest payments, we use the current book value of liabilities D and assume that these liabilities grow at the (continuously compounded) riskfree rate r. Therefore, at time of maturity, the level of debt $D^T = De^{rT}$.

We assume that the market value A follows an Ito process with instantaneous expected drift rate $\mu_A A$ and instantaneous variance rate $\sigma_A^2 A^2$, i.e.,

$$dA = \mu_A A dt + \sigma_A A dz, \tag{3}$$

where dz is a Wiener process with a drift rate of zero and a variance rate of one. Hence, under the assumptions of the Black-Scholes option pricing formula[6], the market value of equity E is given by

$$E = A\Phi\left(d_1\right) - D^T e^{-rT}\Phi\left(d_2\right), \tag{4}$$

[5] In a banking context, see for instance, Ronn and Verma (1986), Furlong (1988), and Hovakimian and Kane (2000).

[6] See, for instance, Hull (1989).

where

$$d_1 = \frac{\ln(A/D^T) + (r + \sigma_A^2/2)T}{\sigma_A\sqrt{T}},$$

$$d_2 = \frac{\ln(A/D^T) + (r - \sigma_A^2/2)T}{\sigma_A\sqrt{T}} = d_1 - \sigma_A\sqrt{T},$$

$\Phi(.)$ is the cumulative normal distribution, and T is the time to maturity.

Inserting $D^T = De^{rT}$ and choosing a time to maturity of one year ($T = 1$)[7], formula (4) can be simplified to

$$E = A\Phi(d_1) - D\Phi(d_2), \tag{5}$$

with

$$d_1 = \frac{\ln(A/D) + \sigma_A^2/2}{\sigma_A},$$

$$d_2 = \frac{\ln(A/D) - \sigma_A^2/2}{\sigma_A} = d_1 - \sigma_A,$$

In addition, according to Ito's Lemma, the standard deviation of E is given by

$$\sigma_E E = \sigma_A A \frac{\partial E}{\partial A} = \sigma_A A \Phi(d_1). \tag{6}$$

We obtain the values of A and σ_A by simultaneously solving equations (5) and (6) numerically using an iterative process.

4 Likelihood of Failure

The likelihood of failure of banks cannot be observed directly. However, using the implied market value and implied volatility of assets derived in the previous section, we can calculate an indicator of default. Our indicator is similar to Furlong's (1988).

[7] By choosing a maturity of one year, we follow Ronn and Verma (1986). To the extent that the maturity of debt differs from one year, this will lead to a bias in the level of the implied volatility. However, since we are mainly interested in *changes* in volatility, this does not pose a problem as long as the maturity is relatively stable.

In contrast to Furlong (1988), however, we also take into account the option value of equity.

The probability of failure is equal to the probability that the value of assets falls below the value of debt at maturity. If asset values follow the stochastic process assumed in (3), the value of assets at maturity A^T is lognormally distributed according to

$$\ln A^T \sim N\left[\ln A + \left(\mu_A - \sigma_A^2/2\right)T, \sigma_A\sqrt{T}\right]. \tag{7}$$

Applying risk-neutral valuation, we can replace μ_A with the riskfree rate of interest r. Again choosing a time to maturity of one year ($T = 1$) and recalling that $D^T = De^{rT}$, the risk-neutral probability that $A^T < D^T$ is equal to

$$\begin{aligned} & \Pr(\ln A^T < \ln D^T) \\ = & \Pr(\ln A^T < r + \ln D) \\ = & \Pr\left(\frac{\ln A^T - \ln A - (r - \sigma_A^2/2)}{\sigma_A} < \frac{r + \ln D - \ln A - (r - \sigma_A^2/2)}{\sigma_A}\right) \\ = & \Pr\left(\frac{\ln(A^T/A) - (r - \sigma_A^2/2)}{\sigma_A} < \frac{\ln(D/A) + \sigma_A^2/2}{\sigma_A}\right). \end{aligned}$$

Hence, the risk-neutral probability of failure is $\Phi(z)$, where z is given by

$$z = \frac{\ln(D/A) + \sigma_A^2/2}{\sigma_A}. \tag{8}$$

The absolute value of z measures the number of standard deviations σ_A that a bank is away from its default point (i.e., the point where $A = D$). Accordingly, $-z$ is sometimes called the 'distance to default'.[8]

Instead of calculating the probability of default, however, we define our indicator of default I as

$$I \equiv -1/z = \frac{\sigma_A}{\ln(A/D) - \sigma_A^2/2}. \tag{9}$$

[8] Another way to derive the probability of default directly is to note that $\Phi(d_2)$ in (5) corresponds to the (risk-neutral) probability that the option is exercised. Therefore, the risk-neutral probability of default is $1 - \Phi(d_2) = \Phi(-d_2)$. This is the same probability as the one derived in the text, as $-d_2 = z$.

Since z is typically negative (i.e., the probability of default is below 0.5), the indicator I is positive. Furthermore, the indicator is monotonically related to the default probability of a bank: The higher the value of I, the higher is the bank's probability of default. From (9) it follows that – as one would intuitively expect – an increase in the asset value A and a decrease in the volatility of assets σ_A lead to a lower probability of default.

5 Data

We use monthly data of 19 publicly traded Swiss banks between January 1990 and April 2002. Balance sheet information is taken from the Swiss National Bank's monthly statistics on individual banks. The annualized volatility of each period t of dividend-adjusted stock returns and of the Swiss bank index are estimated using daily dividend-adjusted stock returns observed over the previous 20 trading days. To test for structural changes over time, we use a dummy for the second half of our sample period. The dummy D_{96-02} takes a value of one between January 1996 and April 2002, and zero otherwise.[9]

Table 1 provides a statistical description of the variables used in the model. Two different definitions are used to compute the capital ratio. c_B is defined as the ratio between accounting capital – the balance sheet total minus total liabilities and asset value adjustments – and balance sheet total. c_M is defined as the ratio between the market value of equity – the (implied) market value of assets minus total liabilities and asset value adjustments – and the (implied) market value of assets.

It is worth noting that for almost every bank and at every point in time, the delta of the option, i.e., $\partial E/\partial A$ in equation (6), is one or very close to one. In other words, for most banks the likelihood of default is close to zero so that the price of the option moves one to one with the value of banks' assets. As a consequence, most of the time the volatility of banks' assets $\sigma_A A$ is simply given by the volatility of the banks' stock

[9] January 1996 not only marks the midpoint of our sample, it also corresponds to the midpoint of a two years period which saw the gradual implementing of changes in the Swiss banks' accounting standards.

returns $\sigma_E E$.

[Insert Table 1 about here]

6 Estimation Results

Equation (1) and (2) are estimated using a two-step FGLS procedure. Table 2 summarizes the results for the estimation of (1). The magnitude and the statistical significance of the relationship between capitalization and risk depends on the definition of capital used. When the capital ratio is computed using market information for assets and equity (Panel A), the relationship between risk and the capital ratio is almost proportional. On average, a 1% increase in the capital ratio is associated with a 1.2% increase in volatility. In addition, this relationship is statistically highly significant and relatively robust to changes in the specification of (1). In particular, neither the magnitude of the relationship, nor its statistical significance are affected by the inclusion of lagged values for $\Delta\sigma_A$ in the estimation.[10] At the individual bank level[11], the relationship between capital and risk is positive for 16 out of 19 banks in our sample and significantly different from zero at the 5% (10%) level for 12 (13) banks. The magnitude of the relationship, however, differs between banks, i.e., the hypothesis that the coefficient for Δc_M is the same for all banks in our sample is (almost) rejected at the 1% level.[12] Finally, the relationship is rather stable over time. As can be seen from D_{96-02} and $\Delta cm * D_{96-02}$, the estimated values of the coefficients do not vary significantly between the period 1990-95 and 1996-02. These findings are partially consistent with Hovakimian and Kane (2000). Using quarterly data for US banks, they show that the market based leverage ratio is negatively correlated with asset risk for their subsamples covering the periods 1985-86 and 1992-94. However, they find a positive correlation between 1987-91.

When the capital ratio is computed using accounting information for assets and

[10] Lags 1 to 6 are statistically significant at the 10% level.

[11] Results at the individual bank level are not reported. They are available upon request.

[12] Under the hypothesis that all coefficients are equal, the Wald test statistic follows a $\chi^2_{18} = 34.38$, with $p\left(\chi^2_{18}\right) > 34.81 = .01$

equity (Panel B), the magnitude as well as the statistical significance of the relationship between risk and capital ratio are reduced. In this case, on average, a 1% increase in the capital ratio is associated with an increase in volatility of .46% and .26%, respectively, depending on the specification adopted.[13] In both cases, the relationship is statistically significant at the 1% and 5% level, respectively.

Table 3 summarizes the results for the estimation of (2). Independently of the measure of banks' capitalization, i.e., either using c_M (Panel A) or c_B (Panel B), and whether or not we include lagged values for z in the estimation, our data suggests that the relationship between capitalization and default probability is weak or nonexistent. In any case, we cannot reject the hypothesis that the effect of Δc_t on the likelihood of failure is 0 at the 10% level of significance, suggesting that the sign and the magnitude of the relationship varies widely between banks. At the individual bank level, the relationship between Δc_M and the likelihood of failure is statistically significant at the 10% level for only 4 banks out of 19. For those banks, the sign of the coefficient of Δc_M is positive, providing weak evidence for a positive relationship between changes in the market definition of capital ratio of a bank and changes in its likelihood of failure, i.e. for those banks, an increase in their capital ratio tend to be accompanied by an increase rather than a decrease of their likelihood to default. Under the alternative definition of capital, the relationship between Δc_B and the likelihood of failure is statistically significant at the 10% level for 7 banks out of 19. Among those, four banks show a positive coeficient while the three remaining banks show a negative one.

[**Insert Tables 2 and 3 about here**]

7 Discussion

Our results suggest that even though banks' risk and their levels of capitalization are positively correlated, there does not seem to be a significant relationship between changes in the capital ratio and the default probability of banks. These results indicate that simple leverage restrictions may not be a sufficient regulatory instrument to ensure

[13] Lags 1 to 6 are statistically significant at the 10% level.

the stability and soundness of banks

Some qualifying comments, however, about our analysis are in order. First, our estimates of the asset values and the asset volatilities are based on a Black-Scholes interpretation of bank equity, which may not be appropriate. In particular, the options approach requires an efficient markets environment. Especially in the context of banking this assumption is questionable. One primary reason for banks' existence is precisely the presence of market frictions and inefficiencies. In other words, the options approach is somewhat paradoxical. Since banks are opaque, risks and true values are not directly observable. In order to circumvent that problem, we deduce these quantities from observed market values – under the assumption that 'the market' is somehow able to assess the true values fairly accurately, despite the banks' opaqueness.

Second, the equations we estimate do not incorporate any other variables that may both affect the capital ratio and the riskiness of banks, potentially leading to biased estimates. In addition, as mentioned by Hovakimian and Kane (2000), in such a setting, the variables in the regression equation are generated synthetically. That is, links between the equations solved may introduce non-zero correlation between the errors in left-hand and right-hand variables of our equation which may render OLS estimators inconsistent. While in principle this could be solved using two-stage least squares, the lack of adequate instruments available on a monthly basis prevents us from doing such a correction.

Finally, Swiss banks are currently not subject to any leverage restrictions. The question is, whether our measured relationship between leverage and risk would still hold if banks were facing a mandatory leverage requirement. In general, we would expect behavior to be affected by the introduction of a new rule. To the extent, however, that the observed combinations of risk and leverage that we observe now are chosen voluntarily, imposing a certain leverage would be equivalent to the regulator picking one particular risk-leverage combination out of all the feasible possibilities. Within the range of our sample, therefore, behavior should not be affected substantially. In contrast, if banks were required to maintain leverage ratios that are well outside the range of values observed in our sample, changes in behavior are quite possible. For instance, Kim and Santomero (1988) have shown that banks that face a strictly binding capital requirement may have an incentive to increase their risk to compensate for the higher level of capital they have to hold. This implies that our results have to be interpreted with caution when trying to make predictions about the impact of any potential leverage requirements.

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Table 1

	Mean	s.e.	Min.	Max.
Market value of assets (V_M; million CHF)	61339	180044	839	1320166
Accounting value of assets (V_B; million CHF)	49781	153900	827	1254901
Market value of capital (k_M; million CHF)	5312	18720	.820	138701
Accounting value of capital (V_B; million CHF)	2265	5843	27	42908
Market value of capital ratio ($c_M = k_M/V_M$)	.099	.096	.001	.520
Accounting value of capital ratio ($c_B = k_B/V_B$)	.057	.032	.006	.384
Annualized std. dev. of rate of return on assets (σ_A)	.018	.031	.000	.329
Annualized std. dev. of bank stock index (σ_{BSI})	.18	.110	.049	.822

Number of observations: 2013

Correlation between c_M and c_B is .57.

Table 2

Two stage FGLS regressions relating changes in the indicator for the likelihood of default ($\Delta\sigma_{A_{i,t}}$) to changes in the capital ratio ($\Delta c_{i,t}$) and changes in the volatility of the Swiss bank stock index ($\Delta\sigma_{BSI_t}$). c_M is the ratio between the market value of equity – the (implied) market value of assets minus total liabilities and asset value adjustments – and the (implied) market value of assets. c_B the ratio between accounting capital – the balance sheet total minus total liabilities and asset value adjustments – and balance sheet total. $\sum_{j=1}^{12}\gamma_j\Delta\sigma_{A_{i,t-j}}$ are lagged values of the risk of banks' assets. D_{96-02} is a dummy variable that takes on the value 1 when the date is between January 1996 and April 2002. Data run from January 1990 to April 2002. Number of observations is 1985 when no lags are included and 1488 when lags are included. 19 banks are included. Average number of observations by bank is 124 without lags and 107 when lags are included. Constants do not differ significantly across banks.

	Panel A: capital ratio = c_M	
Model	$\Delta\sigma_{A_{i,t}} = \alpha_1\Delta c_{i,t} + \alpha_2\Delta\sigma_{BSI_t} + u_{i,t}$	$\Delta\sigma_{A_{i,t}} = \alpha_1\Delta c_{i,t} + \alpha_2\Delta\sigma_{BSI_t} + \sum_{j=1}^{12}\gamma_j\Delta\sigma_{A_{i,t-j}} + u_{i,t}$
Δc_M	1.25*** (6.95)	1.17*** (6.49)
$\Delta\sigma_B$	0.42*** (17.07)	0.35*** (14.3)
$D_{96-02} * \Delta c_M$	-.27 (-1.28)	-.32 (-1.53)
D_{96-02}	.00 (.20)	.03 (1.44)
	Panel B: capital ratio = c_B	
Δc_B	.46*** (3.3)	.26** (2.01)
$\Delta\sigma_B$	.37*** (14.58)	.30*** (11.9)
$D_{96-02} * \Delta c_B$	-.34* (1.84)	-.08 (-.41)
D_{96-02}	.00 (.32)	.03 (1.25)

*, **, *** Indicate values significantly different from zero at the 10 percent, 5 percent and 1 percent levels, respectively. Coefficient $t-$statistics are reported in parentheses.

Table 3

Two stage FGLS regressions relating changes in the indicator for the likelihood of default ($\Delta z_{i,t}$) to changes in the capital ratio ($\Delta c_{i,t}$) and changes in the volatility of the Swiss bank stock index ($\Delta\sigma_{BSI_t}$). c_M is the ratio between the market value of equity – the (implied) market value of assets minus total liabilities and asset value adjustments – and the (implied) market value of assets. c_B the ratio between accounting capital – the balance sheet total minus total liabilities and asset value adjustments – and balance sheet total. $\sum_{j=1}^{12}\gamma_j\Delta z_{i,t-j}$ are lagged values of the risk of banks' assets. D_{96-02} is a dummy variable that takes on the value 1 when the date is between January 1996 and April 2002. Data run from January 1990 to April 2002. Number of observations is 1985 when no lags are included and 1488 when lags are included. 19 banks are included. Average number of observations by bank is 124 without lags and 107 when lags are included. Constants do not differ significantly across banks.

	Panel A: capital ratio $= c_M$	
Model	$\Delta z_{i,t} = \beta_{0,i} + \beta_1\Delta c_{i,t} + \beta_2\Delta\sigma_{BSI_t} + v_{i,t}$	$\Delta z_{i,t} = \beta_{0,i} + \beta_1\Delta c_{i,t} + \beta_3\Delta\sigma_{BSI_t} + \sum_{j=1}^{12}\gamma_j\Delta z_{i,t-j} + v_{i,t}$
Δc_M	.05 (1.06)	.00 (.04)
$\Delta\sigma_B$	.05*** (12.02)	.04*** (9.84)
$D_{96-02} * \Delta c_M$	-.12** (-2.48)	-.06 (-1.29)
D_{96-02}	.00 (.01)	.00 (1.43)
	Panel B: capital ratio $= c_B$	
Δc_B	.02 (.99)	.01 (.05)
$\Delta\sigma_B$	.05*** (12.41)	.04*** (10.15)
$D_{96-02} * \Delta c_B$	-.04 (-1.40)	-.04 (-1.22)
D_{96-02}	-.00 (-.17)	.00 (1.38)

*, **, *** Indicate values significantly different from zero at the 10 percent, 5 percent and 1 percent levels, respectively. Coefficient $t-$statistics are reported in parentheses.