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Does Capital Regulation Matter for Bank Behavior? Evidence for German Savings Banks

by

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Abstract

The aim of this paper is to assess how German savings banks adjust capital and risk under capital regulation. We estimate a modified version of the model developed by Shrieves and Dahl (1992). In comparison to former research, we impose fewer restrictions with regard to the impact of regulation on capital and risk adjustments. Besides, we complement our analysis with dynamic panel data techniques and a rolling window approach.

We find evidence that the coordination of capital and risk adjustments depends on the amount of capital the bank holds in excess of the regulatory minimum (the so-called capital buffer). Banks with low capital buffers try to *rebuild* an appropriate capital buffer by raising capital and simultaneously lowering risk. In contrast, banks with high capital buffers try to *maintain* their capital buffer by increasing risk when capital increases.

Keywords: bank regulation, risk taking, bank capital

JEL classification: G21, G28

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1 Introduction

Since the process of deregulation in the 1970s, supervision of banks has mainly relied on minimum capital requirements. The prominent role of minimum capital requirements is particularly reflected in the Basel Capital Accord and the current process of its revision (Basel II). In Europe, the new standards will be implemented by an EU directive, which will apply to all banks within Europe. However, the importance attached to capital requirements in the supervision of banks raises several questions: How do banks react to capital requirements? Do they increase their Basel capital ratio when they approach the regulatory minimum? And if so, do they adjust their capital, or the risk weighted assets, or both? Do minimum capital requirements also have an effect on well-capitalized banks?

Theoretical work on how banks react to capital requirements is highly sensitive to the underlying assumptions and, thus, comes to contradicting results. Hence, an increasing number of empirical papers have tried to assess the impact of capital requirements on bank behavior. Most of them focus on US banks (Shrieves and Dahl 1992; Jacques and Nigro 1997; Aggarwal and Jacques 2001) while there is only little work done on non-US banks, notably UK and Swiss banks (Ediz et al. 1998; Rime 2001). While US banks seem to adjust capital and risk assets in order to meet the capital regulation, UK and Swiss banks seem to exclusively adjust capital. One plausible explanation for the relative rigidity of Swiss banks' portfolios may be the absence of developed markets for asset-backed securities in Switzerland. In this context, an important contribution of our paper is to provide further empirical evidence on bank behavior in Europe by using German data. In order to mitigate the problem of unobserved heterogeneity, we restrict our analysis to savings banks, which represent a fairly homogenous part of the German banking system. In addition to pooling the data and running 2SLS and 3SLS regressions as done in the literature, we also use dynamic panel data techniques as a robustness check.

Another important contribution of this paper is a new approach to measure regulatory pressure. Former studies define dummy variables depending on the capital ratio of banks. However, the definition of dummy variables is always arbitrary. Hence, we complement the standard dummy approach with a rolling window approach. For the rolling window approach, banks are ordered according to their capital buffers. Then, we estimate our model for observations 1 to n, afterwards for 2 to n+1, and so on, rolling through the whole sample. Finally, we plot the coefficients against the number of recursion and interpret changing coefficient estimates as being due to regulatory influence. The advantage of the rolling window approach is twofold. First, it does not impose restrictions with regard to the impact of regulation on capital and risk adjustments. For instance, the theoretical literature suggests that banks with low capital buffers try to rebuild their capital buffer, while banks with high capital buffers try to maintain their capital buffer. The rolling window approach does allow for this difference in the coordination of capital and risk. In fact, our findings suggest that there is such a difference. In contrast, by largely neglecting this difference, previous research came to ambiguous results. Second, the rolling window approach allows the impact of regulation to change *continuously* depending on the capital position of the bank. In contrast, earlier research assumed a regime shift when banks crossed a threshold arbitrarily chosen by the respective author.

Our paper is organized as follows. Section 2 reviews the literature on capital requirements and bank behavior and specifies the hypotheses to be tested in the remainder of the paper. Section 3 provides a brief overview on German savings banks. Section 4 specifies the empirical model. Section 5 describes the data. Section 6 explains the statistical methodology and shows the regression results. Section 7 concludes.

2 Review of the Literature and Hypotheses

2.1 Theoretical Literature

Capital regulation is often motivated by the assumption of a moral hazard behavior of banks. Information asymmetries and deposit insurance shield banks from the disciplining control of depositors. Merton (1977) shows within an option pricing framework that banks with limited liability can then increase shareholder value by decreasing capital and increasing risk. The increasing default probability goes at the expense of the deposit insurance. Furlong and Keeley (1989) show that – by exposing the bank's own funds to potential risks - flat capital requirements can reduce, but do not eliminate the moral hazard incentives. This is mainly because the amount of capital the bank has to set aside against credit risk does not depend on the bank's asset quality. Sharpe (1978) shows that risk-based capital requirements can completely eliminate moral hazard. Hence, risk-based capital requirements eventually lower the probability of default, thereby lowering the expected liability of the deposit insurance.

Other authors show within portfolio models that flat capital requirements may even increase risk-taking incentives instead of lowering them. Koehn and Santomero (1980) argue that the forced increase in expensive capital financing reduces a bank's expected return. The bank, in turn, tries to increase its profitability by investing in riskier assets. In some cases, the default probability may even increase. Kim and Santomero (1988) and Rochet (1992) point out that risk-based capital requirements can eliminate risk-taking incentives if risk weights are correctly chosen.

The positive assessment of risk-based capital requirements strongly depends on the chosen risk weights. Empirical evidence suggests that the risk weights of Basel I are too crude to reflect the underlying risk. Avery and Berger (1991) find that the capital requirements under Basel I explain only 5% of the banks' loan performance.

The literature reviewed above abstracts from rigidities and adjustment costs. Accordingly, in those models, banks never hold capital in excess of the regulatory minimum. In practice, however, banks may not be able to instantaneously adjust capital or risk due to adjustment costs or illiquid markets. Furthermore, under asymmetric information, capital issues could be interpreted as a negative signal with regard to the bank's value (Myers and Majluf 1984), rendering banks unable or reluctant to react to negative capital shocks instantaneously. However, a breach of the regulation triggers costly supervisory actions, possibly even leading to the bank's closure. Hence, banks have an incentive to hold more capital than required (a so called capital buffer) as an insurance against a violation of the regulatory minimum capital requirement. This incentive increases with the probability of breaching the regulatory minimum and, hence, with the volatility of the capital ratio. However, raising capital is relatively costly compared to raising insured deposits. This trade-off determines the optimum capital buffer (Milne and Whalley 2002).

In summary, the buffer theory argues that banks try to hold a capital buffer on top of the regulatory minimum in order to avoid a violation of minimum capital requirements. Hence, banks with high capital buffers are predicted to aim at *maintaining* their capital buffers while banks with low capital buffers are predicted to aim at *rebuilding* an appropriate capital buffer.

2.2 Hypotheses

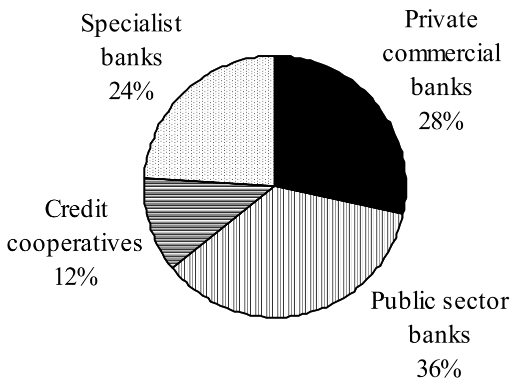
The buffer theory suggests that:
(1) Banks with low capital buffers adjust capital (risk) faster than banks with high capital buffers. The empirical literature finds that banks with low capital buffers adjust capital faster than banks with high capital buffers (Shrieves and Dahl 1992; Ediz et al. 1998; Aggarwal and Jacques 2001). With respect to the adjustment of risk, the aforementioned hypothesis has, to the best of our knowledge, not been tested so far.
(2) Banks coordinate adjustments in capital and risk in order to meet the regulatory capital requirement. To the best of our knowledge, this hypothesis has not been tested exhaustively. The existing literature has studied whether adjustments in capital and risk are positively or negatively related (Shrieves and Dahl 1992; Jacques and Nigro 1997; Aggarwal and Jacques 2001; Rime 2001). The findings are ambiguous. This is not surprising because earlier work did not control for the size of the capital buffer. The buffer theory suggests that banks with low capital buffers try to *rebuild* an appropriate capital buffer by raising capital and simultaneously lowering risk. In contrast, banks with high capital buffers try to *maintain* their capital buffer by increasing capital when risk increases and decreasing capital when risk decreases. This means that, for banks with low capital buffers, adjustments in capital and risk are negatively related while, for banks with high capital buffers, they are positively related.

3 The German Savings Bank Sector

The German banking system is highly fragmented and heterogeneous. To alleviate the problem of unobserved heterogeneity, we focused our analysis on the most homogenous part of the German banking system, which is the savings bank sector.

The German savings banks sector is the largest German banking group, representing 36% (48%) of the balance sheet total of all banks (universal banks) in Germany (Graph 1).

Graph 1: Balance Sheet Total of German Bank Groups, End of 2002



Source: Bundesbank Banking Statistics

German savings banks have some special features, which we have to consider in our analysis. German savings banks are public sector banks, which means that they are owned by communities, districts, or Länder. There are three tiers within the savings bank sector: local saving banks, *Land* banks, and the Deutsche Girozentrale. Local savings banks are municipal or district institutions incorporated under public law as independent legal entities. Local savings banks are usually permitted to operate only in their own region and their investment in securities and other assets are subject to restrictions.

Land banks (Landesbanken) are incorporated under public law and are owned by their respective state government and state savings bank association. The *Land* banks work as clearing houses for their members, the local savings banks. In recent years they also engaged in other banking areas. Through their *Land* bank, local savings banks lend to and borrow from other savings banks in the same administrative region. *Land* banks are state bankers in their respective states and conduct their business on interregional and international basis.

The Deutsche Girozentrale serves as the central clearing bank for the saving bank system and holds the liquidity reserves for the *Land* banks. It is similar to *Land* banks in terms of business, but it is smaller in size than many of them.

For the sake of homogeneity, the *Land* banks and the Deutsche Girozentrale were excluded from the sample as they fulfill the function of central giro institutions for the savings bank sector and have, thus, a very different portfolio.[1]

The mandate of savings banks, which is laid down by the savings bank law, is to foster asset formation and the supply of loans. Originally, their mandate was not commercial profit making, but the provision of loans on favorable terms to less well-off people, to small and medium sized enterprises, and to public authorities in the region of the respective savings bank. Although, public sector banks do follow these lines of business until today, with the passage of time, they have become universal banks. In addition to their original purpose, all saving banks aim at working on profitable terms today. They still operate in their region and hence, do not compete with other savings banks. However, they compete with credit cooperatives in the country side and with commercial banks in cities for most forms of banking business. Because of these special features, savings banks are strongly engaged in lending to non-banks (69.7% of their balance sheet total). Most of this is long-term lending to individuals and to small and medium sized enterprises. As the market for asset-backed securities is currently not very liquid in Germany, the asset structure is rather rigid and cannot be changed rapidly.

Savings banks like all German banks have to comply with the German capital regulation, which is based on the Basel Capital Accord of 1988. Accordingly, banks have to hold capital equal to at least 8% of their risk-weighted assets. Capital is classified in two categories, Tier 1 and Tier 2 capital. Tier 1 capital comprises equity capital and disclosed reserves. Tier 2 capital mainly consists of hybrid debt capital instruments. Its use as liable capital is limited to 100 % of Tier 1 capital.

Savings banks held a total capital buffer, measured as the ratio of total capital to total risk-weighted assets minus 0.08, of more than 3 percentage points in 2002 (see Appendix). Some few banks were close to the regulatory minimum of 8%, whereas some banks held buffers of more than 12%. In comparison, German commercial banks held capital buffers of 6.9 (big banks) and 5.4 (regional banks). A possible explanation why the capital ratio of savings banks is lower than that of commercial banks is the public liability for state-owned banks ("Gewährträgerhaftung"): Public sector banks do not need a capital buffer as high as commercial banks because the public owner pays the liabilities in case of

[1] Free savings banks are also excluded from the sample.

bankruptcy. This public liability guarantees favorable rates of funds. However, as "Gewährträgerhaftung" will have to be eliminated till 18th July 2005, public sector banks will have to increase their capital when competing with commercial banks for low funding rates.

Apart from the public liability, there is another particularity of savings banks with respect to the liability side. The savings bank law forbids saving banks to raise equity capital via capital markets. Hence, they can only raise Tier 1 capital by retained earnings. Besides, at least larger savings banks have the possibility to issue subordinated debt in order to raise Tier 2 capital.

4 Model Specification

4.1 A Simultaneous Equations Model with Partial Adjustment

The theories discussed above presume that banks simultaneously determine capital and risk. Empirical tests of the relationship between capital and risk must recognise this simultaneity. Hence, we use a simultaneous equations model which builds on earlier work by Shrieves and Dahl (1992). The two equations of the model explain capital and risk respectively.

Theory also presumes that banks face shocks in capital and risk. Hence, Hart and Jaffee (1974) and Marcus (1983) point out that the observed changes of capital and risk are not only the result of the discretionary behavior of banks, but also the result of exogenous shocks. With respect to capital, exogenous shocks can be the result of unanticipated changes in earnings. With respect to risk, exogenous shocks are mainly the result of unanticipated economic developments, such as a changing asset or loan quality or a changing value of the loan collateral.[2]

Hence, we model observed changes in capital and risk as the sum of two respective components, a discretionary component and an exogenous random shock:

$$\Delta CAP_{j,t} = \Delta CAP^{d}_{j,t} + \varepsilon_{j,t}\,, \tag{1}$$

$$\Delta RISK_{j,t} = \Delta RISK^{d}_{j,t} + \nu_{j,t}\,, \tag{2}$$

where $\Delta CAP_{j,t}$ and $\Delta RISK_{j,t}$ are the total observed changes, $\Delta CAP^{d}_{j,t}$ and $\Delta RISK^{d}_{j,t}$ are the endogenously determined adjustments, and $\varepsilon_{j,t}$ and $\nu_{j,t}$ are the exogenous random shocks in capital and risk levels, respectively, for bank *j* in period *t*.[3]

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[2] As most of the exogenous shocks are the same for all banks in a given year, we can account for these shocks by including dummy variables for each but one year in the two regression equations (see also below).

[3] Most empirical models do not try to explain the absolute levels of capital and risk. They rather explain the changes in capital and risk. The first reason for this is the fact that a theory of the optimal capital structure for banks is missing. The theories referred to above rather have implications for how individual banks adjust capital to changes in risk (and vice versa). To understand the second reason for this specification, let us assume a mean-variance framework such as in Kim and

The buffer theory additionally presumes that banks face rigidities and adjustment costs, which may prevent them from instantaneous discretionary adjustments. Hence, we model the discretionary part of observed changes in capital and risk in a partial adjustment framework. This framework assumes that banks aim at establishing optimal capital and risk levels, the so-called target levels. Since exogenous shocks drive actual levels away from target levels, banks will then adjust capital and risk to meet the target. However, full adjustment may be too costly and/or infeasible. Hence, banks adjust levels only partially towards the target levels. The partial adjustment framework assumes that the adjustment is proportional to the difference between optimal and actual levels:

$$\Delta CAP_{j,t}^{d} = \alpha(CAP_{j,t}^{*} - CAP_{j,t-1}), \tag{3}$$

$$\Delta RISK_{j,t}^{d} = \beta(RISK_{j,t}^{*} - RISK_{j,t-1}), \tag{4}$$

where α and β are the proportionality factors, $CAP_{j,t}^{*}$ and $RISK_{j,t}^{*}$ are the target levels, and $CAP_{j,t-1}$ and $RISK_{j,t-1}$ are the actual levels of capital and risk, respectively, in the previous period.

Substituting Eqs. (3) and (4) into Eqs. (1) and (2), the observed changes in capital and risk can be written as

$$\Delta CAP_{j,t} = \alpha(CAP_{j,t}^{*} - CAP_{j,t-1}) + \varepsilon_{j,t}, \tag{5}$$

$$\Delta RISK_{j,t} = \beta(RISK_{j,t}^{*} - RISK_{j,t-1}) + \nu_{j,t}. \tag{6}$$

Hence, the observed changes in capital and risk in period *t* are a function of the target levels and the lagged levels of capital and risk, respectively, and exogenous shocks.

4.2 Definitions of Capital and Risk

In the literature, the leverage ratio (Tier 1 or total capital to total assets) or the risk-based capital ratio (Tier 1 or total capital to risk-weighted assets) are common measures of capital. While Shrieves and Dahl (1992) use the first measure, the second measure has become more popular after the introduction of risk-based capital regulation. It is used by Jacques and Nigro (1997) and Ediz et al. (1998). Aggarwal and Jacques (2001) and Rime (2001) use both measures in separate specifications. However, we opt for the total capital to total assets as a

Santomero (1988). Banks with relatively low risk aversion will then choose relatively high leverage and relatively high asset risk. We would, thus, expect to observe a negative cross-sectional correlation between the level of asset risk and capital ratios due to cross-sectional variation in risk preferences. However, the second reason is less important for our study of German savings banks as they are a rather homogenous group. Differences in risk aversion may not play a prominent role.

measure of capital. Total capital consists of all liable capital components which the German Banking Law allows.[4] The total capital definition is comparable to the total capital definition of Basel I. The reason why we opt for this capital measure will be explained after the definition of risk.

The definition of risk is more problematic. More advanced measures, such as value at risk or expected shortfall, are usually not available. The same holds true for the volatility of the market price of a bank's assets. Instead, the literature mostly uses the ratio of risk-weighted assets to total assets (RWATA) as an alternative risk measure, data of which is – at least in principle - available. The rationale for this measure is that the allocation of bank assets among risk categories is the major determinant of a bank's risk.[5] Shrieves and Dahl (1992) points out that, apart from allocation, a bank's portfolio risk is also determined by the quality of loans. They argue that the quality of loans is best measured by the ratio of non-performing loans to total assets. Hence, they add a third equation to their model which defines risk as the ratio of non-performing loans to total loans.[6] Jacques and Nigro (1997) contradict Shrieves and Dahl (1992). They argue that the RWATA captures the allocation as well as the quality aspect of portfolio risk, whereas Avery and Berger (1991) and Berger (1995) argue that this ratio is positively correlated with risk. Jacques and Nigro (1997) and Rime (2001) exclusively rely on RWATA, while Aggarwal and Jacques (2001) use both measures in separate specifications. Following the majority of the literature, we opt for the RWATA as a measure of risk.

The reason, why we use the leverage ratio and RWATA as a measure of capital and risk, respectively is the following. The Basel I capital requirement is defined in terms of total capital to total risk-weighted assets. In order to comply with the 8% regulatory minimum, banks can manage the numerator and/or the denominator of the Basel capital ratio. In the definitions chosen in this paper, *dCAP* reflects adjustments in the numerator (capital) while *dRISK* reflects adjustments in the denominator (risk assets). Hence, *dCAP* and *dRISK* can be interpreted as the two variables banks have at their discretion to manage their Basel capital ratio. This interpretation is logically independent of whether or not *RISK* is a correct measure of risk. The interpretation as a measure of risk is only correct if the risk weights correctly reflect the economic risk of the assets. However, empirical evidence shows that the Basel I risk weights and the economic risk of an asset are only weakly correlated (Avery and Berger 1991). But still, all banks, whatever additional risk measures they use in their daily business, will have to obey regulatory rules. In this sense, they will have to

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4 Total capital is defined as core capital plus additional capital minus corrective items specified by the German Banking Law.

5 Support for this measure can be found in Chessen (1987) and Keeton (1989).

6 Support for this measure can be found in Meeker and Gray (1987), Beaver et al. (1989), and Nejezchleb and Morgan (1990).

manage their "regulatory" risk. Despite the shortcomings of RWATA as a measure of risk and in line with the literature, we interpret *RISK* as a measure of risk in the remainder of the paper. However, readers with doubts might want to replace "risk" by "risk assets" for what follows.

4.3 Variables Affecting the Target Levels of Capital and Risk

The partial adjustment model suggests that banks aim at establishing their target capital and risk levels. These target levels are not readily observable. They depend on other variables specific to the individual bank. In the following, these explanatory variables and their expected impact on the observed changes in capital and risk are presented.

4.3.1 Size

Size may have an effect on a bank's target capital level as the size of a bank may be an indicator of the bank's access to capital. Savings banks as publicly owned entities are not allowed to raise Tier 1 capital via equity markets. Hence, they depend on retained earnings and capital injections by their public owners. However, big savings banks use subordinated debt issues to raise Tier 2 capital. Besides, size may also have an effect on a bank's target risk level as the size of a bank affects its investment opportunities and diversification possibilities. The sign of this effect is, however, undetermined (Acharya et al. 2002). The natural log of total assets (SIZE) is included in the capital and risk equations to capture size effects.

4.3.2 Current Profits

Current profits are expected to have a positive effect on a bank's capital ratio. As German law prohibits savings banks to raise equity capital via capital markets, savings banks mainly increase capital through retained earnings. Hence, the bank's return on assets (ROA) is included in the capital equation as a measure of profits with an expected positive sign.

4.3.3 Current Loan Losses

Current loan losses affect the ratio of risk-weighted assets to total assets as they reduce the nominal amount of risk-weighted assets. Building on Rime (2001), we approximate these losses (LLOSS) with the ratio of new net provisions to total assets and include LLOSS in the risk equation with an expected negative sign.

4.3.4 Regulatory Pressure

The literature suggests two ways to measure regulatory pressure. The first is the probabilistic approach introduced by Ediz, Michael, Perraudin (1998) and later used by Rime (2001). The hypothesis behind this approach is that the bank's capital and risk decisions are constrained by regulatory pressure once the bank falls close to the minimum capital requirement. However, the definition of closeness depends not only on the absolute percentage difference between the current capital ratio and the minimum capital requirement, but also on the variability of the capital ratio. Hence, we divide the absolute percentage difference by the bank-specific standard deviation of this percentage difference in order to obtain the banks' standardized capital buffers. We include a regulatory dummy (REG) in the regression equations, which is unity if a bank has a standardized capital buffer equal or less than the median standardized capital buffer over all observations, and zero otherwise.

The second way to measure regulatory pressure is the prompt corrective action (PCA) based approach introduced by Aggarwal and Jacques (1998) and later used by Rime (2001). The hypothesis is that the quality of regulatory pressure changes once banks fall below certain regulatory thresholds. In the US, the Federal Deposit Insurance Corporation improvement Act defines a series of capital thresholds used to determine what supervisory actions would be taken by bank regulators. The PCA zones start even above the regulatory minimum of 8%. It is straightforward to model such an explicit PCA scheme by regulatory dummies corresponding to different PCA zones (Aggarwal and Jacques 1998). In Germany however, such an explicit PCA scheme does not exist. The only threshold is the 8% regulatory minimum, which the bank has to maintain by all means. Therefore, in our sample, we observe only one bank with capital ratios less than 8%. As this bank cannot be assumed to take deliberate capital decisions, but to be under control of supervisors, it is dropped from the sample. Hence, the PCA based approach to measure regulatory pressure is not suitable for Germany and we focus on the probabilistic approach instead.[7]

[7] In his study on the Swiss banking sector, Rime (2001) modelled two PCA zones, the first below 8% and the second between 8% and 10%. However, the second PCA zone does not officially exist and is, hence, arbitrarily chosen by the author. As

Under the probabilistic approach, the definition of the regulatory dummy is arbitrary. It is not clear whether there is a regime shift at a certain threshold, i.e. that banks behave differently when they are one or two or three standard deviations above the regulatory minimum. Thus, in order to check the robustness of our results, we use three different approaches. As we assume that banks with high capital buffers behave differently than banks with low capital buffers, we first choose the capital threshold such that half of the banks are classified as having a low capital buffer and half as having a high capital buffer. For our sample, this threshold is at 2.62 (2.53) standard deviations of the capital buffer above the 8% regulatory minimum for the pooled regression (dynamic panel regression). Second, we complement this approach by splitting the sample according to the same threshold and estimate both subsamples separately. Third, we give up the assumption of a regime shift and allow for a continuous shift of behavior depending on the size of the capital buffer. For this purpose, we use a rolling window approach, which has not been employed in this context so far.

4.3.5 Simultaneous Changes in Risk and Capital

The theories discussed above presume that banks simultaneously determine the level of capital and risk. The simultaneity of those decisions requires the inclusion of both endogenous variables on the right hand side of the two equations. We expect that, according to the buffer theory, adjustments in capital and risk are positively related for banks with high capital buffers while they are negatively related for banks with low capital buffers. In order to allow for the different relationships between capital and risk within the dummy approach, we interact *dRISK* and *dCAP* with the regulatory dummy and additionally include this interaction term in the regression.

4.3.6 Macroeconomic Shocks

Besides, macroeconomic shocks may affect the demand for and structure of loans as well as the supply of deposits. As such macroeconomic shocks are the same for all banks, we account for these shocks by including dummy variables for each but one year into the regression equations.

German supervisors cannot be assumed to take actions before banks fall below the 8% regulatory minimum, we do not follow this approach.

4.4 Specification

With regard to the analysis above, the empirical model defined by Eqs. (5) and (6) is specified as follows:

$$\Delta CAP_{j,t} = \alpha_0 + \alpha_1 REG_{j,t} + \alpha_2 ROA_{j,t} + \alpha_3 SIZE_{j,t} + \alpha_4 \Delta RISK_{j,t} - \alpha_5 CAP_{j,t-1} + \alpha_6 REG_{j,t} * \Delta RISK_{j,t} - \alpha_7 REG_{j,t} * CAP_{j,t-1} + \beta_8 dy1995 + ... + \beta_{14} dy2001 + u_{j,t} \quad (7)$$

$$\Delta RISK_{j,t} = \beta_0 + \beta_1 REG_{j,t} + \beta_2 LLOSS_{j,t} + \beta_3 SIZE_{j,t} + \beta_4 \Delta CAP_{j,t} - \beta_5 RISK_{j,t-1} + \beta_6 REG_{j,t} * \Delta CAP_{j,t} - \beta_7 REG_{j,t} * RISK_{j,t-1} + \beta_8 dy1995 + ... + \beta_{14} dy2001 + w_{j,t} \quad (8)$$

α_5 and β_5 can be interpreted as the speed of adjustment in capital and risk respectively. In order to test whether banks with low capital buffers adjust capital and risk faster than banks with high capital buffers, we interact $CAP_{j,t-1}$ and $RISK_{j,t-1}$ with the regulatory dummy and additionally include this interaction term in the regression. This approach is more comprehensive compared to earlier research which allows only for a higher speed of capital adjustments.

5 Data Description

The sample consists of about 550 German savings banks over the period 1994 to 2002. The data was obtained from Deutsche Bundesbank, which collects bank-level data in its prudential function. 1993 was the earliest date for which data on risk assets was available for savings banks. However, we need the data for 1993 for forming the first differences and the lags. 2002 was the latest date for which data was consistently available at the time this paper was written. However, data was complete for only 324 out of the 500 savings banks.

Throughout the observation period, the 4982 banks under study held an average capital buffer of 2.65 standard deviations above the 8% regulatory minimum. The lowest (highest) capital buffer in the sample was 0.0025 (14.14). Excluding the lowest and the highest 5% from the sample leaves the capital buffers ranging between 0.73 and 4.80. In this paper, we decided to classify capital buffers as low (high) when they are below (above) the median value of 2.62. Table 1 shows the mean values of the variables separately for banks with low and with high capital buffers. The mean values of the variables for each year are given in the appendix.

Table 2 gives the correlations for all non-categorical variables, including relevant first differences and lags. In addition, it gives the correlations for the capital buffer measured in standard deviations above the regulatory minimum. The correlations are based on the pooled sample. The correlation between levels of CAP and RISK as well as between first differences of CAP and RISK are positive. This finding stands in contrast to Shrieves and Dahl (1992), who find a negative correlation between levels and a positive correlation between first differences. They argue that the negative correlation between levels is due to cross-sectional variation in risk preferences: Banks with low risk aversion would choose low capital ratios and high risk, whereas banks with high risk aversion would choose high capital ratios and low risk. However, in this paper, savings banks were deliberately chosen as they are assumed to be a rather homogenous group of banks. Hence, the lacking cross-sectional variation in risk aversion is not surprising.

Table 1: Variable Means for Banks with Low and High Capital Buffers

	Banks with Low Capital Buffer[a] REG=1	Banks with High Capital Buffer[b] REG=0
dCAP	0.0021	0.0026
dRISK	0.0104	0.0056
ROA	0.0025	0.0024
SIZE	20.6073	20.6688
LLOSS	0.0040	0.0032
CAP_{t-1}	0.0518	0.0588
$RISK_{t-1}$	0.5274	0.5426
Capital buffer[c]	0.0212	0.0336
Capital buffer[d]	1.6818	3.6144
Nb. of obs.	2491	2491

[a] Banks with capital buffers lower than 2.62 standard deviations above the 8% regulatory minimum. – [b] Banks with capital buffers higher than 2.62 standard deviations above the 8% regulatory minimum. – [c]Measured as the Basel capital ratio minus 0.08. – [d]Measured in standard deviations above the 8% regulatory minimum.

Table 2: Correlations among Variables

	CAP	RISK	dCAP	dRISK	ROA	SIZE	LLOSS	Capital buffer[a]
CAP	1.0000							
RISK	0.7053	1.0000						
dCAP	0.1286	-0.0630	1.0000					
dRISK	0.0289	0.1096	0.1867	1.0000				
ROA	0.0916	0.0660	0.1260	0.0267	1.0000			
SIZE	0.1077	0.1008	-0.0433	-0.0311	-0.0626	1.0000		
LLOSS	-0.0727	0.0228	0.0259	-0.0227	-0.4277	0.0406	1.0000	
Capital buffer[a]	0.3597	-0.3846	0.2540	-0.0902	0.0309	0.0177	-0.1139	1.0000
Capital buffer[b]	0.3519	0.0681	0.0764	-0.0697	-0.0054	0.0085	-0.1073	0.3572

[a]Measured as the Basel capital ratio minus 0.08. – [b]Measured in standard deviations above the 8% regulatory minimum.

6 Methodology and Regression Results

6.1 Dummy Approach in a Pooled Regression

In this subsection, we pool the cross-sectional data over all nine years of the reference period, as done by Shrieves and Dahl (1992), Jacques and Nigro (1997), Aggarwal and Jacques (2001), and Rime (2001). The time dimension is taken into account by including dummy variables for each but one year of the reference period.

In a simultaneous equations model, the regressors include endogenous variables. In contrast to the ordinary least squares estimator, the two and three stage least squares (2SLS/3SLS) estimator take account of this endogeneity and, hence, produce consistent estimates.[8] 3SLS produces asymptotically more efficient estimates than 2SLS as 3SLS uses the information that the disturbance terms in the two structural equations are contemporarily correlated.[9]. As, for our sample, 2SLS and 3SLS produce quite similar estimates, we present only the 3SLS estimates.

The results of estimating the simultaneous system of Eqs. (7) and (8) are presented in Table 3. We present three different specifications which vary in the way how the regulatory variable affects the capital and risk decisions of banks. Moving from the least complex to the more advanced approaches, Specification I allows adjustments in capital and risk to depend on whether banks have low or high capital buffers (inclusion of *REG*); Specification II additionally allows for higher speeds of adjustment in capital and risk (inclusion of *REG* and $REG*CAP_{t-1}$ and $REG*RISK_{t-1}$, respectively); finally, Specification III additionally allows for differences in the coordination of capital and risk adjustments (inclusion of *REG* and *REG*dRISK* and *REG*dCAP*, respectively).

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[8] 2SLS and 3SLS are an instrumental variables approach which use a linear combination of all exogenous variables as instruments for the endogenous regressors. In the specifications where we include dyREG*dRISK and dyREG*dCAP among the regressors, we also use instrumental variables for these interaction terms. As a combination of all exogenous variables uses the most information possible in the construction of an instrument, 2SLS and 3SLS produce both consistent and efficient estimates.

[9] 3SLS was introduced by Zellner and Theil (1962).

The results of Specification I show that mainly all of the variables are significant and have the expected sign. As expected, the return on assets (*ROA*) has a statistically highly significant and positive effect on capital. Hence, savings banks seem to rely strongly on retained earnings in order to increase capital. Loan losses (*LLOSS*) show also the expected significant and negative effect on risk. Bank size (*SIZE*) has a statistically significant and negative effect on both capital and risk. The negative effect on capital is in line with the empirical literature and means that larger banks increase capital less than smaller banks. A possible explanation is that larger savings banks have access to the bond market. Hence, the optimal capital buffer of larger banks is smaller than the optimal capital buffer of smaller banks because larger savings banks have access to alternative funds. However, the negative effect of bank size on risk is in contrast to most other papers and means that larger banks have lower target risk levels than smaller banks.

The parameter estimate of *dRISK* in the capital equation is statistically highly significant and negative while the parameter estimate of *dCAP* in the risk equation is statistically insignificant. This means that banks decrease capital when risk increases. However, they do not adjust risk when capital changes. We will not interpret these coefficients further here because we believe that we have to differentiate between the case of banks with high capital buffers and the case of banks with low capital buffers in order to get reasonable results (see below).

The parameter estimates of lagged capital and risk are statistically highly significant. They show the expected negative sign and lie in the required interval of [0;-1]. Hence, they can be interpreted as the speeds of adjustment in capital and risk. The speed of adjustment in capital (0.1023) is about three times higher than the speed of adjustment in risk (0.0362). The estimated speeds of adjustment mean that shocks to capital and risk are halved after 6.42 and 18.80 years, respectively. Hence, the estimated speeds of adjustment are relatively slow.

The results in Table 3 provide some interesting insights regarding the impact of capital regulation on changes in capital and risk. In Specification I, we measure the impact of capital regulation in a fairly simple way by including a regulatory dummy variable, thereby allowing banks with low capital buffers to increase capital and decrease risk by more than other banks. However, the estimation of Specification I gives the opposite results of what we expected. The parameter estimates of the regulatory dummy variable are statistically highly significant and negative in the capital equation and positive in the risk equation. The results suggest that banks with low capital buffers increase capital by 0.07 percentage points less than other banks and decrease risk by 0.61 percentage points less than other banks. This counterintuitive result may be due to the fact that we measure regulatory pressure simply by including a dummy variable, but that the impact of regulation is more complex.

In Specification II, we additionally interact the parameters of lagged capital and risk with the regulatory dummy. Hence, we allow banks with low capital buffers to adjust capital and risk faster than banks with high capital buffers. With respect to the capital equation, the coefficient of the interaction term is significant and has the expected sign. The results suggest that banks with low capital buffers adjust capital faster than other banks. The estimated speed of capital adjustment is 0.1221 (=0.0940+0.0281) for banks with low capital buffers compared to 0.0940 for banks with high capital buffers.[10] Besides, in Specification II and in contrast to Specification I, the coefficient of the regulatory dummy is significant and has the expected positive sign.[11] With respect to the risk equation, the interaction term has the expected negative sign, suggesting that banks with low capital buffers adjust risk assets faster than other banks (0.0412 compared to 0.0302). Besides, the inclusion of the interaction term does not change the counterintuitive positive sign of the coefficient of the regulatory dummy variable.

In Specification III, we additionally interact the regulatory variable with the respective adjustment terms in capital and risk. Hence, we additionally allow banks with low capital buffers to differ in the coordination of capital and risk adjustments from banks with high capital buffers. In accordance to our second hypothesis, we expect that banks with low capital buffers try to build up their capital buffer by increasing capital and/or decreasing risk. Therefore, adjustments in risk and capital should have a negative sign in both equations. It is also sufficient for our hypothesis to hold that only one of the two coefficients is negative while the other one is insignificant. We also expect that banks with high capital buffers try to maintain their capital buffers by increasing capital when risk increases and decreasing capital when risk decreases. Therefore, adjustments in risk and capital should have a positive sign in both equations. It is again sufficient that only one of the two coefficients is positive while the other one is insignificant.

The estimation results support our hypothesis. We find that the estimated coefficients of *dRISK* and *REG*dRISK* are insignificant while the estimated coefficients of *dCAP* and *REG*dCAP* are statistically highly significant. The coefficient of *dCAP* is positive (2.9260) and absolutely smaller than the coefficient of *REG*dCAP*, which is found to be negative (-4.7278). The results suggest that banks with low capital buffers decrease risk when they increase capital, thereby rebuilding their capital buffer. In contrast, banks with high capital buffers increase risk when capital increases, thereby maintaining their capital buffer. However, banks with low capital buffers as well as banks with

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[10] The estimated speed of capital adjustment in Specification I is, hence, approximately the average of the two different speeds of adjustment of banks with low capital buffers and of banks with high capital buffers.

[11] When we take both effects together (0.0010-0.0281*0.0518=-0.00045), the influence of regulation on capital adjustments is negative as given by the coefficient of the regulatory dummy variable in Specification I.

high capital buffers do not adjust capital when risk changes. This finding indicates that the coordination of capital and risk adjustments runs only from capital to risk and not vice versa. Although we did not expect the coordination to be one-way, the findings are in line with the buffer theory. Besides, Specifications I and II suggest also a one-way coordination, but they suggest the coordination to run from risk to capital and, hence, the other way around.

Concerning the speed of adjustment, the estimated coefficient of $REG*RISK_{t-1}$ is statistically significant and negative while the estimated coefficient of $REG*CAP_{t-1}$ is statistically insignificant. The results suggest that banks with low capital buffers adjust risk twice as fast as banks with high capital buffers (0.0454=0.0227+0.0227 compared to 0.0227), but they do not adjust capital significantly faster. While the finding with respect to a higher speed of risk adjustment is in line with the finding of Specifications II, the finding with respect to a constant speed of capital adjustment is in contrast to the finding of Specifications II.

In summary, the dummy approach suggests that regulation has an impact on the speed of capital and risk adjustment and the coordination of capital and risk. However, the results are ambiguous with respect to whether regulation affects capital and risk adjustments or only one of the two. These ambiguous results may be due to the restrictive assumptions concerning the impact of regulation. We could expand the dummy approach by interacting all variables with the regulatory dummy and including all interaction terms in the regression. This approach would allow all coefficients to vary depending on whether the bank holds a higher or lower standardized capital buffer than the median bank. An alternative approach, which we shall follow in the sequel, is to stratify the sample.

Table 3: Pooled 3SLS Estimates for Specifications with Regulatory Dummy and Interactions Terms for 1994-2002

	I		II		III	
	Coefficient	z-Value	Coefficient	z-Value	Coefficient	z-Value
	dCAP		dCAP		dCAP	
REG	-0.0007***	-4.25	0.0010*	1.76	-0.0002	-0.35
ROA	0.3365***	8.35	0.3346***	8.42	0.3396***	8.75
SIZE	-0.0001**	-2.00	-0.0002**	-2.50	-0.0001*	-1.92
dRISK	-0.0860***	-4.86	-0.1129***	-7.37	-0.0481	-1.49
REG*dRISK					-0.0388	-1.29
CAP_{t-1}	-0.1045***	-14.02	-0.0940***	-10.07	-0.0969***	-9.34
REG*CAP_{t-1}			-0.0281***	-2.65	-0.0035	-0.31
dy1994	-0.0015***	-4.37	-0.0017***	-4.65	-0.0016***	-4.66
dy1995	-0.0015***	-4.44	-0.0015***	-4.35	-0.0016***	-4.77
dy1996	-0.0011***	-2.87	-0.0012***	-3.32	-0.0011***	-2.99
dy1997	-0.0015***	-4.77	-0.0015***	-4.64	-0.0016***	-5.07
dy1998	-0.0012***	-3.99	-0.0010***	-3.16	-0.0014***	-4.30
dy1999	-0.0013***	-4.34	-0.0011***	-3.61	-0.0015***	-4.62
dy2000	0.0002	0.57	0.0008**	2.08	-0.0002	-0.38
dy2001	-0.0013***	-4.30	-0.0012***	3.84	-0.0013***	-4.57
Intercept	0.0123***	7.57	0.0125***	7.42	0.0115***	6.91
	dRISK		dRISK		dRISK	
REG	0.0061***	7.50	0.0114***	3.41	0.0297***	5.30
LLOSS	-0.1969**	-2.44	-0.2155***	-2.79	-0.2222**	-2.52
SIZE	-0.0011***	-2.91	-0.0011***	-2.95	-0.0010**	-2.48
dCAP	0.3137	0.78	-0.2563	-0.65	2.9260***	4.05
REG*dCAP					-4.7278***	-5.56
$RISK_{t-1}$	-0.0362***	-10.13	-0.0302***	-6.25	-0.0227***	-3.81
REG*$RISK_{t-1}$			-0.0110*	-1.82	-0.0227***	-2.89
dy1994	-0.0049***	-2.85	-0.0043**	-2.48	-0.0031*	-1.66
dy1995	-0.0016	-0.98	-0.0012	-0.72	-0.0008	-0.45
dy1996	-0.0094***	-5.46	-0.0085***	-4.87	-0.0080***	-4.39
dy1997	-0.0034**	-2.04	-0.0032*	-1.94	-0.0016	-0.88
dy1998	0.0052***	3.06	0.0049***	2.85	0.0075***	4.02
dy1999	0.0034**	1.99	0.0030*	1.72	0.0050***	2.70
dy2000	0.0187***	11.02	0.0184***	10.66	0.0196***	10.73
dy2001	0.0012	0.71	0.0007	0.43	0.0024	1.29
Intercept	0.0455***	5.51	0.0445***	5.19	0.0281***	2.88
Nb. of obs.	4982		4982		4982	

***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively, in a two-tailed t-test.

6.2 Dummy Approach in a Dynamic Panel Regression

In the last section, the data was pooled over time. Pooling, however, assumes that the unobserved heterogeneity, i.e. bank-specific effects, is negligible. If this assumption is incorrect, the coefficient estimates of the pooled regression are biased. Although we have tried to reduce the problem of unobserved heterogeneity by choosing the most homogenous banking group in Germany, in this section, we model the behavior of banks in a dynamic panel data context as a robustness check. If the results are similar, the bank-specific effects do not play a dominant role and we can return to the computationally simpler pooled estimator for the rest of the paper.

In order to be able to use the software package DPD for Ox (Doornik et al. 2002), we need to transform Eqs. (5) and (6) such that the levels of $CAP_{j,t}$ and $RISK_{j,t}$ instead of the first differences are the regressands. Hence, we add $CAP_{j,t-1}$ and $RISK_{j,t-1}$ to both sides of Eqs. (7) and (8) respectively. The system to be estimated is the following:

$$\begin{aligned} CAP_{j,t} &= \alpha_0 + \alpha_1 REG_{j,t} + \alpha_2 ROA_{j,t} + \alpha_3 SIZE_{j,t} + \alpha_4 \Delta RISK_{j,t} \\ &+ (1-\alpha_5) CAP_{j,t-1} + \alpha_6 REG_{j,t} * \Delta RISK_{j,t} - \alpha_7 REG_{j,t} * CAP_{j,t-1} \\ &+ dy1995 + ... + dy2001 + u_{j,t} \end{aligned} \tag{9}$$

$$\begin{aligned} \Delta RISK_{j,t} &= \beta_0 + \beta_1 REG_{j,t} + \beta_2 LLOSS_{j,t} + \beta_3 SIZE_{j,t} + \beta_4 \Delta CAP_{j,t} \\ &+ (1-\beta_5) RISK_{j,t-1} + \beta_6 REG_{j,t} * \Delta CAP_{j,t} - \beta_7 REG_{j,t} * RISK_{j,t-1} \\ &+ dy1995 + ... + dy2001 + w_{j,t} \end{aligned} \tag{10}$$

where $u_{j,t} = \mu_j + \varepsilon_{j,t}$ and $w_{j,t} = \eta_j + v_{j,t}$ with $\mu_j \sim IID(0, \sigma_\mu^2)$, $\eta_j \sim IID(0, \sigma_\mu^2)$, $\varepsilon_{j,t} \sim IID(0, \sigma_\varepsilon^2)$ and $v_{j,t} \sim IID(0, \sigma_v^2)$, independent of each other and among themselves.

Unlike previous empirical studies of the Shrieves and Dahl type, we employ dynamic panel data techniques which control for the bank-specific effects μ_j and η_j. The Within estimator is known to produce biased estimates when the lagged dependent variable appears as a regressor.[12] The bias will approach zero as T goes to infinity (Nickell 1981). In our case, T is relatively small compared to N. Hence, we have basically two possibilities, either to correct the Nickell bias or to use an instrumental variable approach. Monte Carlo simulations suggest that the Within estimator with the Kiviet (1995) correction outperforms all other estimators in small samples (Judson and Owen 1999). However, we do not have a small sample and besides, the implementation of this estimator for unbalanced panels has not been derived. Hence, we use an instrumental variables approach.

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[12] Since $\Delta CAP_{j,t}$ is a function of μ_j, $CAP_{j,t-1}$ is also a function of μ_j. Hence, $CAP_{j,t-1}$, a right-hand regressor in Eq. (7), is correlated with the error term. This renders the 2SLS and 3SLS estimator biased and inconsistent. For the fixed effects estimator, the Within transformation eliminates the μ_j, but $(CAP_{j,t-1} - \overline{CAP}_{j.-1})$ where $\overline{CAP}_{j.-1} = \sum_{t=2}^{T} CAP_{j,t-1}/(T-1)$ will still be correlated with $(\varepsilon_{j,t} - \bar{\varepsilon}_j)$ as $CAP_{j,t-1}$ is correlated with $\bar{\varepsilon}_j$ by construction. $\bar{\varepsilon}_j$ contains $\varepsilon_{j,t-1}$, which is correlated with $CAP_{j,t-1}$. Therefore, the fixed effects estimator will be biased (Nickell 1981). Besides, the random effects GLS estimator is also biased because before applying GLS, quasi-demeaning is performed.

We take the first difference of the model in order to eliminate the individual effect μ_j and try to find suitable instruments for $CAP_{j,t-1} - CAP_{j,t-2}$.[13] Arellano and Bond (1991) suggest a Generalized Method of Moments (GMM) estimator which uses the entire set of lagged values of CAP_j as instruments. However, in models with endogenous regressors, using too many instruments in the later cross-sections could result in seriously biased estimates. Hence, we only use a subsample of the whole history of the series as instruments in the later cross-sections. Besides, a possible persistence in observed capital and risk adjustments may result in the problem of weak instruments and losses in asymptotic efficiency when using the Arellano and Bond GMM estimator (Blundell and Bond 1998). Alternatively, Blundell and Bond suggest to use a so-called system GMM estimator.[14] They use the fact that where instruments are available that are uncorrelated with the individual effect, these variables can be used as instruments for the equations in levels. Hence, lagged differences of CAP_j are used as instruments for equations in levels, in addition to lagged levels of CAP_j that are used as instruments for equations in first differences. As, for our sample, the one- and two-step Blundell-Bond GMM estimator produce quite similar estimates, we present only the two-step estimates as they are asymptotically more efficient.[15]

In contrast to the pooled regressions, we run the panel regressions only on the subperiod from 1994 to 2000. The reason is that the Sargan's (1958) test of over-identifying restrictions is very sensitive to coefficient estimates not being stable over time. Capital and risk adjustments in 2001 and 2002 seem to be too strongly influenced by the burst of the bubble for the Sargan test to indicate valid instruments. Besides, we keep only banks in the sample which exist for at least four years during the observation period.

As we have noted above, Sargan's test of over-identifying restrictions is very sensitive to coefficient estimates not being stable over time. Although we have reduced this problem by excluding the time periods after the burst of the bubble, in the case of the risk equation, the Sargan test still indicates that we use invalid instruments. However, as it is well known that the Sargan test indicates invalid instruments too often, we still interpret our results in the following though with due caution.

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[13] We use the capital equation as an example in what follows. The same considerations in the choice of instruments hold for the risk equation.

[14] The system GMM estimator may not be confused with the pooled 3SLS system estimator. The GMM estimator does not take the contemporaneous correlations between the two equations into account. In this respect, it is rather comparable to the pooled 2SLS estimator.

[15] In addition to lagged levels of *CAP* as instruments for $CAP_{j,t-1}$-$CAP_{j,t-2}$ in the difference equations and first differences as instruments in the level equations, we also use *LLOSS* and lagged levels of *RISK* as instruments for $dRISK_{j,t}$-$dRISK_{j,t-1}$ in the difference equations and first differences as instruments in the level equations in order to account for the simultaneity of capital and risk adjustments.

The results of estimating the simultaneous system of Eqs. (9) and (10) are presented in Table 4. The Sargan test and the condition for consistency of the GMM estimator, i.e. the (lack of) evidence for first-order (second-order) serial correlation in the first-differenced residuals are also presented. We present two different specifications which vary in the way how the regulatory dummy variable is defined. In Specification I, the dummy variable equals one for banks with capital buffers up to the median capital buffer (2.528687) and zero else. Hence, Specification I is analogous to Specification III in the pooled regression. In Specification II, the dummy variable equals one for banks with capital buffers up to the 25% centile (1.691821) and zero else. Hence, the dummy variable captures banks which are closer to the 8% regulatory minimum and can, thus, be thought to take regulatory pressure stronger into account.

The results of Specification I and II show that, as in the pooled regression, the return on assets (*ROA*) has a statistically highly significant and positive effect on capital. However, the estimated coefficient is much smaller. Loan losses (*LLOSS*) show also the expected significant and negative effect on risk although they are significant in Specification II only. In contrast to the pooled regression, bank size (*SIZE*) has a statistically significant and negative effect only on risk but not on capital.

With respect to lagged capital, we estimated and report $(1-\alpha_5)$ and not α_5. Hence, we have to subtract 1 in order to get the speed of adjustment. The estimated speeds of adjustment are 0.1023 (v = (0.8977-1)/0.02312 = -4.42 where 0.02312 is the estimated standard error) as well as 0.094 (-61,53) in the capital equation for Specifications I and II and 0.045 (-3.46) and 0.032 (-4.28) in the risk equation. Hence, the estimated speeds are highly significant and lie in the range given by the pooled regression.

With respect to the impact of regulation, the results partly confirm the results of the pooled regression. The regulatory dummy (*REG*) is also insignificant in the risk equation. Besides, the interaction terms of *REG* and lagged capital and risk are insignificant. Hence, the results suggest that banks with low capital buffers do not adjust capital and risk faster than banks with high capital buffers. In addition, the results suggest again that banks adjust capital faster than risk but that the speed of adjustment is slow. Finally, with respect to the coordination of capital and risk adjustments, we find that, in the capital equation, the coefficient of *dRISK* is insignificant while the interaction term of *REG* and *dRISK* is significant and negative. In the risk equation, the significance depends on the definition of the regulatory dummy. While the coefficient estimates of *dCAP* and of the interaction term of *REG* and *dCAP* are found to be insignificant in Specification I, they are found to be significant in Specification II. Furthermore, in Specification II, the coefficient estimate of *dCAP* is positive (2.1784) and absolutely smaller than the coefficient of *REG*dCAP*, which is found to be negative (-8.5985). The results suggest that, when using the narrower definition of the regulatory dummy, our hypothesis of a negative (positive) coordination for banks with low (high) capital buffers is confirmed. In contrast to the results of the pooled regression, we find a two-way coordination for banks with low capital buffers.

Table 4: Blundell-Bond Two-Step GMM Estimates for Specifications with Regulatory Dummy and Interactions Terms for 1994-2000

	I		II	
	Coefficient	z-Value	Coefficient	z-Value
	CAP		CAP	
REG	-0.0032	-1.17	-0.0012	-0.34
ROA	0.1860***	2.61	0.1820**	2.30
SIZE	-0.0001	-0.84	-0.0002	-1.64
dRISK	0.0514	1.59	-0.0098	-0.36
REG*dRISK	-0.1272**	-2.38	-0.1409*	-1.88
CAP_{t-1}	0.8977***	38.80	0.9060***	62.50
REG*CAP_{t-1}	0.0401	0.79	0.0080	0.11
T1996	0.0007**	2.05	0.0004	0.96
T1997	-0.0003	-1.11	-0.0004	-1.40
T1998	-0.0009***	-2.71	-0.0007*	-1.74
T1999	-0.0008**	-2.26	-0.0007*	-1.94
T2000	-0.0002	-0.38	0.0001	0.09
Intercept	0.0102***	3.42	0.0119***	4.15
Sargan test	$Chi^2(26)$ = 23.94 [0.579]		$Chi^2(26)$ = 24.11 [0.570]	
AR(1) test	N(0,1) = -8.736 [0.000]***		N(0,1) = -8.192 [0.000]***	
AR(2) test	N(0,1) = 1.744 [0.081]*		N(0,1) = 1.260 [0.208]	
	RISK		RISK	
REG	-0.0090	-0.63	0.0063	0.34
LLOSS	-0.1225	-1.03	-0.2554**	-2.09
SIZE	-0.0022***	-4.81	-0.0016***	-3.19
dCAP	1.0323	0.93	2.1784**	2.34
REG*dCAP	-1.4279	-1.06	-8.5985***	-3.44
$RISK_{t-1}$	0.9546***	72.60	0.9680***	129.00
REG*$RISK_{t-1}$	0.0377	1.49	0.0356	1.09
T1996	-0.0077***	-5.96	-0.0077***	-5.38
T1997	-0.0011	-0.78	-0.0009	-0.54
T1998	0.0073***	4.22	0.0083***	4.61
T1999	0.0060***	3.68	0.0062***	3.48
T2000	0.0204***	12.00	0.0222***	10.70
Intercept	0.0702***	4.78	0.0497***	3.59
Sargan test	$Chi^2(29)$ = 59.01 [0.001]***		$Chi^2(29)$ = 51.73 [0.006]***	
AR(1) test	N(0,1) = -10.69 [0.000]***		N(0,1) = -8.625 [0.000]***	
AR(2) test	N(0,1) = -0.5293 [0.597]		N(0,1) = 0.4765 [0.634]	
Nb. of obs. (banks)	3368 (572)		3368 (572)	

***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively, in a two-tailed t-test. Sargan test refers to the test of over-identifying restrictions. AR(1) and AR(2) test refers to the test for the null of no first-order and second-order autocorrelation in the first-differenced residuals.

All in all, when using the narrower definition of the regulatory dummy, the results of the panel regression mainly confirm the results of the pooled regression with regard to the sign of the coefficient estimates. In particular, they again confirm our hypothesis with regard to the coordination of capital and risk adjustments. Hence, as we are particularly interested in the sign of the coefficient estimates as it gives the direction of the relationship between the variables, we will return to the computationally simpler pooled regression for what follows.

6.3 Subsample Approach

We split the sample according to whether the bank holds a higher or lower capital buffer than the median bank. We then estimate the following system of equations:

$$\begin{aligned}\Delta CAP_{j,t} &= \alpha_0 + \alpha_2 ROA_{j,t} + \alpha_3 SIZE_{j,t} + \alpha_4 \Delta RISK_{j,t} - \alpha_5 CAP_{j,t-1} \\ &+ dy1995 + \ldots + dy2001 + \varepsilon_{j,t}\end{aligned} \quad (11)$$

$$\begin{aligned}\Delta RISK_{j,t} &= \beta_0 + \beta_2 LLOSS_{j,t} + \beta_3 SIZE_{j,t} + \beta_4 \Delta CAP_{j,t} - \beta_5 RISK_{j,t-1} \\ &+ dy1995 + \ldots + dy2001 + v_{j,t}\end{aligned}, \quad (12)$$

where the regulatory dummy and the interaction terms have been eliminated compared to Eqs. (7) and (8). We compare the coefficient estimates of the two subsamples and interpret different estimates as being due to the different capital buffers. We compare the respective confidence intervals and interpret two estimates as different if the confidence intervals do not overlap. As the allocation of the banks into the two subsamples is endogenous, a fully econometrically valid test is not straightforward. However, our procedure is a first indicator of whether two estimates are statistically different.

The results are given in Table 5. The subsample approach shows that *SIZE* matters only for banks with low capital buffers. *SIZE* has a negative effect on capital and risk, which is consistent to what we found under the dummy approach. As before, *LLOSS* is significant (and negative) only for banks with low capital buffers, but insignificant for banks with high capital buffers.

With regard to the impact of regulation on the speed of adjustment of capital and risk, the results confirm the findings of the dummy approach in the pooled regression only partly. While the speed of capital adjustment is also found to be higher for banks with low capital buffers than for banks with high capital buffers, the speed of risk adjustment is not found to be significantly higher. Again, the speeds of adjustment are again found to be relatively low.

Table 5: 3SLS Estimates for Two Subsamples for 1994-2002

	Banks with Low Capital Buffer[a]				Banks with High Capital Buffer[b]			
	Coefficient	z-Value	95% Confidence Interval		Coefficient	z-Value	95% Confidence Interval	
	dCAP				dCAP			
ROA	0.3102***	5.69	0.2034	0.4170	0.3147***	5.40	0.2005	0.4290
SIZE	-0.0003**	-2.39	-0.0005	-0.0001	0.0000	-0.58	-0.0002	0.0001
dRISK	-0.1373***	-7.11	-0.1751	-0.0994	0.0073	0.23	-0.0555	0.0700
CAP_{t-1}	-0.1264***	-11.67	-0.1476	-0.1052	-0.0700***	-6.33	-0.0917	-0.0483
dy1994	-0.0025***	-3.46	-0.0040	-0.0011	-0.0009*	-1.89	-0.0018	0.0000
dy1995	-0.0026***	-3.66	-0.0041	-0.0012	-0.0008**	-2.09	-0.0016	0.0000
dy1996	-0.0024***	-3.00	-0.0040	-0.0008	-0.0004	-0.96	-0.0011	0.0004
dy1997	-0.0025***	-3.26	-0.0039	-0.0010	-0.0014***	-4.95	-0.0020	-0.0009
dy1998	-0.0010	-1.42	-0.0023	0.0004	-0.0021***	-5.94	-0.0028	-0.0014
dy1999	-0.0018***	-2.62	-0.0031	-0.0005	-0.0017***	-5.03	-0.0023	-0.0010
dy2000	0.0007	1.03	-0.0006	0.0020	-0.0014**	-2.07	-0.0028	-0.0001
dy2001	-0.0015**	-2.20	-0.0028	-0.0002	-0.0013***	-4.58	-0.0019	-0.0007
Intercept	0.0170***	6.07	0.0115	0.0225	0.0080***	4.45	0.0045	0.0115
	dRISK				dRISK			
LLOSS	-0.2460***	-2.68	-0.4257	-0.0664	0.0269	0.20	-0.2413	0.2950
SIZE	-0.0018***	-2.99	-0.0030	-0.0006	-0.0003	-0.73	-0.0012	0.0006
dCAP	-0.9648*	-1.85	-1.9852	0.0555	1.6924***	2.69	0.4605	2.9243
$RISK_{t-1}$	-0.0440***	-8.53	-0.0541	-0.0339	-0.0249***	-4.85	-0.0350	-0.0149
dy1994	-0.0126***	-3.68	-0.0193	-0.0059	-0.0038	-1.55	-0.0086	0.0010
dy1995	-0.0117***	-3.46	-0.0183	-0.0051	0.0049**	2.16	0.0005	0.0093
dy1996	-0.0188***	-5.24	-0.0258	-0.0118	-0.0043**	-2.20	-0.0082	-0.0005
dy1997	-0.0151***	-4.25	-0.0221	-0.0082	0.0031*	1.66	-0.0006	0.0067
dy1998	-0.0031	-0.87	-0.0100	0.0039	0.0097***	4.84	0.0058	0.0136
dy1999	-0.0064*	-1.76	-0.0135	0.0007	0.0085***	4.41	0.0047	0.0123
dy2000	0.0109***	3.12	0.0041	0.0177	0.0213***	10.94	0.0175	0.0252
dy2001	-0.0044	-1.24	-0.0115	0.0026	0.0029	1.52	-0.0008	0.0067
Intercept	0.0824***	6.30	0.0568	0.1080	0.0161	1.50	-0.0050	0.0371
Nb. of observ.	2491				2491			

[a] Banks with capital buffers lower than 2.62 standard deviations above the 8% regulatory minimum. – [b] Banks with capital buffers higher than 2.62 standard deviations above the 8% regulatory minimum. – ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively, in a two-tailed t-test.

With regard to the impact of regulation on the coordination of capital and risk adjustments, the subsample approach confirms the findings of the dummy approach in the dynamic panel regression (Specification II). The estimated coefficient of *dCAP* is statistically significant and negative for banks with low capital buffers and positive for banks with high capital buffers. Furthermore, the estimated coefficient of *dRISK* is also statistically significant and negative for banks with low capital buffers. This finding suggests that banks with low capital buffers increase capital and simultaneously decrease risk in order to rebuild their capital buffers. In contrast, banks with high capital buffers increase risk when capital increases, but they do not adjust capital when risk changes. Hence, for banks with low capital buffers, coordination runs from capital to risk and vice versa while, for banks with high capital buffers, it only runs from capital to risk.

6.4 Rolling Window Approach

Measuring regulatory pressure by a dummy variable makes a rather restrictive assumption. It assumes that banks behave differently when passing a certain threshold capitalization which we arbitrarily set equal to 2.62 standard deviations above the 8% regulatory minimum, the capitalization of the median bank. The subsample approach builds on the same assumption. However, a regime shift at a certain threshold capitalization is not supported by economic theory. Instead, a continuous change of behaviour seems more plausible. Hence, we complement the dummy approach with a rolling window approach.

For the rolling window approach, banks are ranked according to their capital buffers. The bank with the lowest capital buffer (measured in standard deviations above the 8% regulatory minimum) takes the first position while the bank with the highest capital buffer takes the last position. We then estimate Eqs. (11) and (12) for different subsamples. The first regression includes observations 1 to n, which contain the banks with the n lowest capital buffers. We repeat the same estimation for the observations 2 to n+1 etc., subsequently rolling through the whole sample. Finally, we plot the estimated coefficients and the 95% confidence interval against the corresponding number of recursion.

The advantage of the rolling window approach is that it is unnecessary to model the regulatory influence explicitly. The regulatory influence on the banks' behavior is implicitly reflected in changing coefficient estimates. According to our hypotheses, the regulatory influence is expected to be primarily reflected in the speed of adjustment and in the coordination of capital and risk adjustments. Graph 2 shows the results for savings banks for a rolling sample of 750 banks over the pooled sample of 4982 banks.

To a large degree, the results confirm the results of the dummy and subsample approach. We find that the estimated coefficient of the return on assets (*ROA*) is highly significant and positive for most recursions. The coefficient of loan loss provisions (*LLOSS*) is insignificant for most of the recursions. Only for recursions including banks with medium sized capital buffers, the estimated coefficient becomes significantly negative. These observations seem to drive the negative result of the dummy approach. All in all, *LLOSS* does not seem to have a significant impact on the target level of risk assets for most German savings banks. The coefficients of *SIZE* in the capital as well as the risk equation are not significant for most of the recursions. This is in contrast to the result of the dummy approach in the dynamic panel regression (subsample approach), which finds a highly significant and negative effect on (capital and) risk.

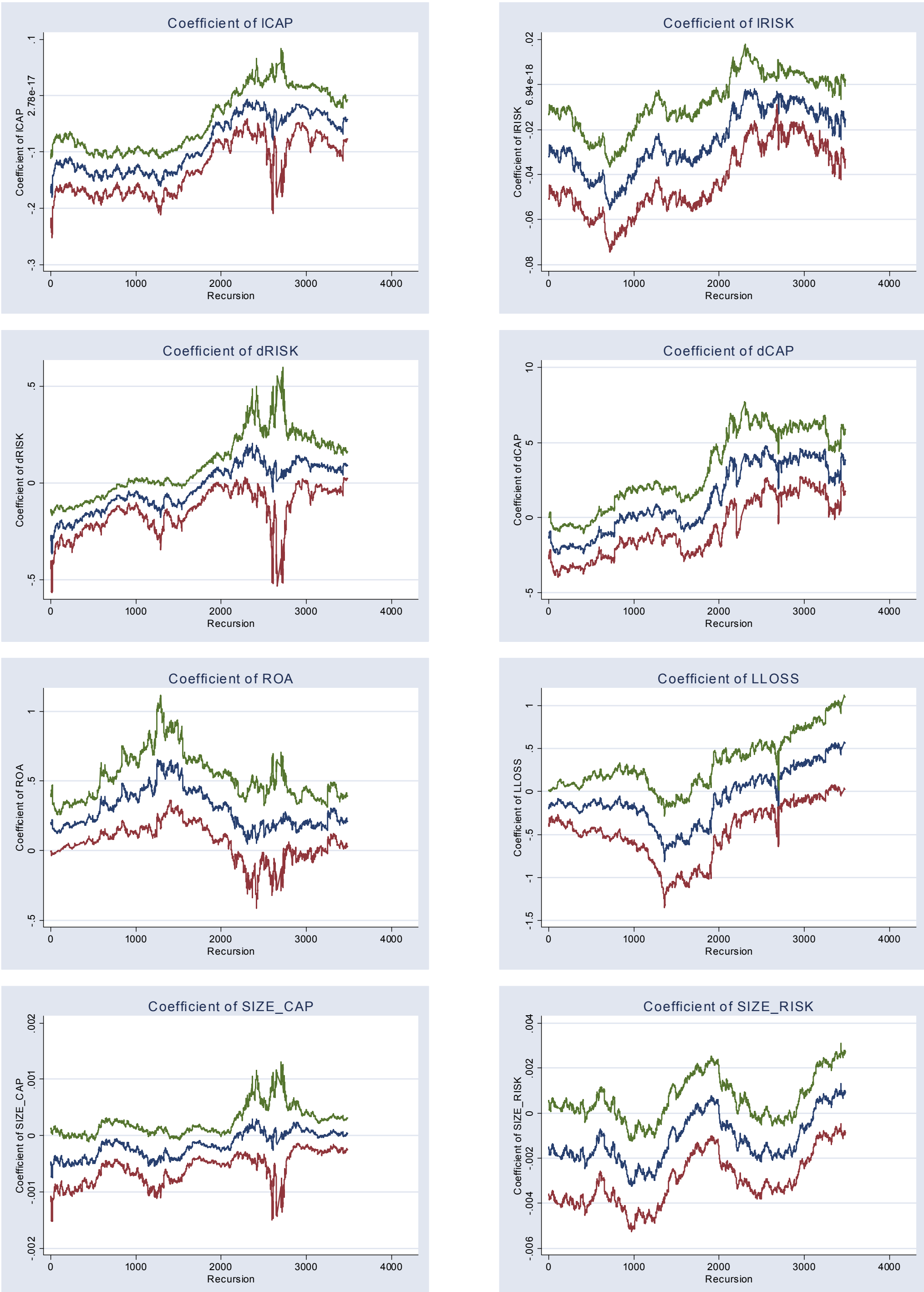
With respect to the speed of adjustment, the estimated coefficients of lagged capital and risk are significant and have the expected negative sign. Only for banks with high capital buffers, the coefficients become insignificant. With respect to capital, the estimated speed of adjustment is relatively stable around 0.14 for banks with low capital buffers. For banks with medium-sized capital buffers, the speed of adjustment decreases significantly until it becomes zero for banks with high capital buffers.

With respect to risk, the coefficient does not move significantly with the number of recursion, i.e. the speed of risk adjustment is independent of the size of the capital buffer. Hence, banks are found to vary the speed of adjustment in capital in response to their capital position, but not the speed of risk adjustment. Besides, the estimated speed of risk adjustment varies between 0.05 and zero. Thus, banks adjust capital faster than risk. However, the speed of capital and risk adjustment is again found to be rather slow.

The rolling window approach gives a clearer picture of how German savings banks coordinate adjustments in capital and risk assets than the dummy approach and the subsample approach. For banks with low capital buffers, the coefficients of *dRISK* and *dCAP* are statistically significant and negative while, for banks with high capital buffers, only the coefficient of *dCAP* is statistically significant and positive. These findings are in line with the findings of the dummy approach in the dynamic panel regression and the subsample approach. Hence, on the one hand, banks with low capital buffers try to *rebuild* an appropriate capital buffer by raising capital and simultaneously lowering risk. On the other hand, banks with high capital buffers try to *maintain* their optimum capital buffer by increasing risk when capital increases. However, banks with high capital buffers do not adjust capital when risk changes. In addition to the subsample approach, the rolling window approach shows that, for banks with medium-sized capital buffers, the coefficients of *dRISK* and *dCAP* are not significant. This result indicates that banks with medium-sized capital buffers do *not* coordinate adjustments in capital and risk assets.

Graph 2: Estimated Coefficients for a Rolling Window of 750 German Savings Banks

The graphs give the estimated coefficients as well as the upper and lower bound of the 95% confidence interval. The coefficient is significant at the 5% level if the zero is not included in the interval.



7 Conclusion

In this paper, we examine how German savings banks adjust capital and risk during the period 1994-2002. We are particularly interested in the question how banks consider capital regulation in their capital and risk decisions. We estimate a modified version of the model developed by Shrieves and Dahl (1992). In addition to the standard dummy approach in a pooled regression used by the literature, we use dynamic panel data techniques as a robustness check. Compared to former research, we impose fewer restrictions with regard to the impact of regulation on capital and risk adjustments. We complement this dummy approach with a rolling window approach. The rolling window approach has the advantage that it does not impose ad hoc restrictions with regard to the impact of regulation on capital and risk adjustments. Furthermore, this approach allows the impact of regulation to change continuously depending on the amount of capital the bank holds in excess of the regulatory minimum (the so-called capital buffer).

We find that regulation has an impact on adjustments in capital and risk assets in several interesting respects. In line with the literature, we find that banks adjust capital faster than risk. In contrast to the literature, we find mixed evidence that banks with low capital buffers adjust capital faster than banks with high capital buffers. Besides, we also find mixed evidence for risk adjustments. With respect to the coordination of capital and risk, we find evidence that banks with low capital buffers try to *rebuild* an appropriate capital buffer by raising capital and simultaneously lowering risk. In contrast, banks with high capital buffers try to *maintain* their capital buffer by increasing risk when capital increases. However, banks with high capital buffers do not adjust capital when risk changes. Besides, banks with medium-sized capital buffers do not seem to coordinate capital and risk. In summary, our findings are in line with the hypotheses derived from the buffer theory.

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Appendix

Descriptive Statistics

	Mean	Minimum	5 percentile	Median	95 percentile	Maximum
dCAP	0.0023	-0.0182	-0.0032	0.0021	0.0090	0.0306
dRISK	0.0080	-0.3250	-0.0291	0.0072	0.0485	0.2851
ROA	0.0024	-0.0266	0.0004	0.0024	0.0049	0.0187
SIZE	20.6381	17.4928	19.1153	20.6471	22.2569	23.9673
LLOSS	0.0036	-0.0213	-0.0006	0.0030	0.0098	0.0768
CAP_{t-1}	0.0553	0.0123	0.0336	0.0560	0.0726	0.1147
$RISK_{t-1}$	0.5350	0.1796	0.3207	0.5553	0.6707	0.8203
Capital buffer[a]	0.0274	0.0000	0.0071	0.0235	0.0610	0.1586
Capital buffer[b]	2.6481	0.0025	0.7303	2.6193	4.7985	14.1424

[a] Measured as the Basel capital ratio minus 0.08. – [b] Measured in standard deviations above the 8% regulatory minimum.

Variable Means for Each Year of the Observation Period

	1994	1995	1996	1997	1998	1999	2000	2001	2002
dCAP	0.0031	0.0027	0.0037	0.0024	0.0017	0.0016	0.0016	0.0015	0.0026
dRISK	0.0056	0.0076	-0.0013	0.0036	0.0117	0.0097	0.0250	0.0060	0.0032
ROA	0.0028	0.0030	0.0028	0.0026	0.0024	0.0023	0.0022	0.0019	0.0013
SIZE	20.3454	20.4600	20.5521	20.6117	20.6680	20.7328	20.7811	20.8590	20.9166
LLOSS	0.0030	0.0046	0.0044	0.0041	0.0036	0.0013	0.0035	0.0036	0.0050
CAP_{t-1}	0.0451	0.0485	0.0512	0.0550	0.0573	0.0591	0.0606	0.0622	0.0648
$RISK_{t-1}$	0.5059	0.5163	0.5256	0.5246	0.5275	0.5398	0.5478	0.5715	0.5862
Capital buffer[a]	0.0148	0.0187	0.0261	0.0303	0.0315	0.0325	0.0303	0.0320	0.0359
Capital buffer[b]	1.7873	2.0019	2.6259	2.9390	2.9457	3.0006	2.7569	2.9125	3.2537
Nb. of banks	621	611	599	591	585	569	554	528	324

[a] Measured as the Basel capital ratio minus 0.08. – [b] Measured in standard deviations above the 8% regulatory minimum.