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Does capital regulation matter for bank behaviour? Evidence for German savings banks

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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). This paper contributes to the literature in three ways. First, we test the capital buffer theory (Marcus 1984, Milne and Whalley 2002). Second, we use dynamic panel data techniques that explicitly take unobserved heterogeneity into account. And third, we provide new evidence for non-US banks by using a new dataset of supervisory data collected by the Deutsche Bundesbank. 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 "capital buffer"). Banks with low capital buffers try to *rebuild* an appropriate capital buffer by raising capital while simultaneously lowering risk. In contrast, banks with high capital buffers try to *maintain* their capital buffer by increasing risk when capital increases. These findings support the capital buffer theory.

Keywords: bank regulation, risk taking, bank capital

JEL classification: G21, G28

Non-technical Summary

Economic theory provides contradictory results about banks' reaction to minimum capital requirements. The empirical literature has mainly tested the moral hazard theory, building on a model developed by Shrieves and Dahl (1992). The discussion paper "Does capital regulation matter for bank behaviour" focuses on an alternative theory, the capital buffer theory (Marcus 1984, Milne and Whalley 2002). The capital buffer is the excess capital a bank holds above the minimum capital requirement. The capital buffer theory implicates that banks with low capital buffers attempt to rebuild an appropriate capital buffer and banks with high capital buffers attempt to maintain their capital buffer. We derive testable hypotheses for the capital buffer theory based on the model of Shrieves and Dahl and provide empirical evidence for German savings banks and cooperative banks.

Our findings support the capital buffer theory. The most important results are:

1. The coordination of capital and risk adjustments depends on the amount of capital the bank holds in excess of the regulatory minimum (the "capital buffer").

2. Banks with low capital buffers try to *rebuild* an appropriate capital buffer by raising capital while simultaneously lowering risk.

3. Banks with high capital buffers try to *maintain* their capital buffer by increasing risk when capital increases.

4. We find mixed (no) evidence that banks with low capital buffers adjust capital (risk) faster than banks with high capital buffers.

Nichttechnische Zusammenfassung

Die Auswirkungen regulatorischer Kapitalanforderungen auf das Verhalten von Banken sind von theoretischer Seite unklar. Üblicherweise beschränkt sich die empirische Literatur zu diesem Thema auf die Untersuchung der Moral-Hazard-Theorie und benutzt dazu das Modell von Shrieves und Dahl (1992). Das Diskussionspapier "Does capital regulation matter for bank behaviour" untersucht einen alternativen Erklärungsansatz, die Kapitalpuffertheorie (Marcus 1984, Milne and Whalley 2002). Als Kapitalpuffer bezeichnet man das Überschusskapital, das über der regulatorischen Mindestanforderung gehalten wird. Die Kapitalpuffertheorie impliziert, dass Banken mit niedrigem Kapitalpuffer bemüht sind, den Puffer wieder aufzubauen, während Banken mit hohem Kapitalpuffer versuchen, die Kapitalausstattung konstant zu halten. Im vorliegenden Beitrag wird, ebenfalls ausgehend vom Modell von Shrieves und Dahl, ein Test für die Kapitalpuffertheorie vorgeschlagen. Gleichzeitig werden empirische Ergebnisse für deutsche Sparkassen und Kreditgenossenschaften präsentiert.

Die empirische Studie bestätigt die Kapitalpuffertheorie. Im einzelnen zeigen sich folgende Ergebnisse:

1. Die Koordination der Kapital- und Risikoanpassungen hängt von der Höhe des Kapitalpuffers ab.

2. Banken mit geringem Kapitalpuffer versuchen einen angemessenen Kapitalpuffer *aufzubauen*, indem sie gleichzeitig ihre Kapitalausstattung verbessern und ihre Risikopositionen reduzieren.

3. Demgegenüber versuchen Banken mit hohem Kapitalpuffer den Kapitalpuffer zu *halten*, indem sie ihre Risikopositionen erhöhen, wenn die Kapitalausstattung steigt.

4. Die These, dass Banken mit niedrigem Kapitalpuffer ihr Kapital (bzw. Risiko) schneller anpassen als solche mit einem hohen Kapitalpuffer, ist empirisch nicht bzw. nicht eindeutig zu belegen.

Contents

Does capital regulation matter for bank behaviour? Evidence for German savings banks*

1 Introduction

Since the process of deregulation in the 1970s, the supervision of banks has mainly relied on minimum capital requirements. This prominent role of minimum capital requirements is particularly reflected in the Basel Capital Accord and the current process of its revision (Basel II). 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 capital when they approach the regulatory minimum? Do they also adjust risk and how are these adjustments interrelated? And finally, do minimum capital requirements also have an effect on well-capitalized banks?

An increasing branch of the theoretical literature has tried to assess the effects of minimum capital requirements on capital and banks' risk. This literature argues mainly within option pricing models or portfolio models and that capital regulation is motivated mostly by the assumption that banks commit moral hazard. Information asymmetries and deposit insurance shield banks from the disciplining control of depositors. Merton (1977) shows within an option pricing model that banks with limited liability can thus increase shareholder value by decreasing capital and increasing risk. The increasing default probability is 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

* We thank Jörg Breitung, Claudia Buch, Kai Carstensen, Stefan Jaschke, Phil Molyneux, and Andrea Schertler for helpful comments.

requirements can completely eliminate moral hazard. Hence risk-based capital requirements eventually lower the probability of default, thereby lowering the expected deposit insurance liability.

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 traditional moral hazard 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, raising equity capital 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 "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 (Marcus 1984, Milne and Whalley 2002).

The moral hazard theory and the capital buffer theory have different implications for how banks adjust capital and risk in the light of minimum capital requirements. The moral hazard theory predicts that when capital requirements force banks to increase capital, they will react by also increasing risk. By contrast, the capital buffer theory predicts that the behaviour of banks depends on the size of their capital buffer: banks with high capital buffers will aim at *maintaining* their capital buffers while banks with low capital buffers will aim at *rebuilding* an appropriate capital buffer. Hence for banks with high capital buffers, capital and risk adjustments will be positively related while, for banks with low capital buffer, capital and risk adjustments will be negatively related.

An increasing number of empirical papers (Shrieves and Dahl 1992; Jacques and Nigro 1997; Aggarwal and Jacques 2001; Rime 2001) has tried to test the moral hazard theory. Most papers find a positive relationship between capital and risk adjustments, indicating that banks that have built up capital have, at the same time, also increased risk. This finding has been interpreted as supporting the moral hazard theory.

We contribute to the literature in three important ways. First, to the best of our knowledge, we are the first to empirically test the capital buffer theory. To do so, we allow the relationship between capital and risk adjustments to depend on the size of the capital buffer. Second, in contrast to much of the literature, we do not pool the data, but use dynamic panel data techniques in order to account explicitly for bank-specific effects. And third, we use a new supervisory dataset collected by the Deutsche Bundesbank. While most of the existing literature studies US banks, we study German banks, thereby providing further evidence on non-US banks.

Our paper is organised as follows. Section 1 specifies the empirical model and the hypotheses to be tested. Section 2 and 3 describe the data and the statistical methodology. Section 4 shows the regression results. Section 5 concludes.

2 The empirical model

2.1 A simultaneous equations model with partial adjustment

The capital buffer and the moral hazard theory 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 adjustments in capital and risk respectively.[1] As the observed adjustments are the result not only of the discretionary behaviour of banks but also of exogenous shocks, adjustments are modelled as the sum of a discretionary component and an exogenous random shock:[2]

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

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

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 $\nu_{i,t}$ are the exogenous random shocks in capital and risk levels, respectively, for bank *j* in period *t*.

1 Most empirical models do not try to explain the absolute levels of capital and risk. Instead, they explain adjustments in capital and risk. The first reason for this is the fact that a theory of the optimal capital structure for banks does not exist. The theories referred to above, rather, have implications for how individual banks adjust capital in reaction to adjustment 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 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.

2 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 (Hart and Jaffee 1974 and Marcus 1983).

The buffer theory additionally assumes that banks face rigidities and adjustment costs that may prevent them from making instantaneous discretionary adjustments. Hence we model the discretionary part of observed adjustments in capital and risk in a partial adjustment framework. This framework assumes that banks aim at establishing optimal capital and risk levels, the "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:

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

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

where α and β are the speeds of adjustments, $CAP^{*}_{j,t}$ 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 adjustments 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 adjustments in capital and risk in period *t* are a function of the target levels and the lagged levels of capital and risk respectively as well as exogenous shocks.

1.2 Definitions of capital and risk

We define capital (*CAP*) as the ratio of total capital to total assets (TCTA). Total capital consists of all liable capital components permitted under the German Banking Act and is comparable to the definition used in the Basel Capital Accord.[3] The definition of risk is more problematic. More advanced measures, such as value at risk, are not available. The same holds for the volatility of the market price of a bank's assets. Instead, we define risk (*RISK*) as the ratio of risk-weighted assets to total assets (RWATA). The rationale for this definition is that the allocation of bank assets among risk categories is the major determinant of a bank's risk.[4]

Another reason why we use TCTA and RWATA as definitions of capital and risk, respectively is the following. The Basel I minimum capital requirement is defined as the ratio of total capital to total risk-weighted assets. In order to comply with the 8% regulatory minimum, banks can adjust 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-weighted 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 correct only 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). However, regardless of whatever additional risk measures they use in their daily business, all banks still have to obey regulatory rules. In this sense, they will have to 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-weighted assets" in the following.

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3 Total capital is defined as core capital plus additional capital minus corrective items specified by the Banking Act.

4 Support for this measure can be found in Chessen (1987) and Keeton (1989). Shrieves and Dahl (1992) point out that, apart from allocation, a bank's portfolio risk is also determined by the quality of loans. In contrast, Jacques and Nigro (1997) 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.

1.3 Variables affecting the target levels of capital and risk

The partial adjustment model presented in Eqs. (5) and (6) above 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 adjustments in capital and risk are presented.

Size may have an effect on a bank's target capital level as the size of a bank is an indicator of the bank's access to capital. German law prohibits savings banks from raising Tier 1 capital via equity markets. Hence savings banks depend on retained earnings and capital injections by their public owners. However, big savings banks use subordinated debt issues to raise Tier 2 capital.[5] Thus, larger savings banks are more flexible in raising capital, which renders their target capital level smaller than the target capital levels of smaller banks. 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). Hence we include the natural log of total assets (*SIZE*) in the capital and risk equations to capture size effects.

Savings banks have to rely mainly on retained earnings to increase capital. Hence we include the bank's return on assets (*ROA*) in the capital equation as a measure of profits with an expected positive sign.

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.

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5 Of the 50 banks with the highest number of subordinated debt issues in Basel Committee member states 15 are German savings banks: 7 central giro institutions and 8 local savings banks (Basel Committee on Banking Supervision 2003).

Besides, we use two control variables which may also affect target capital and risk levels. First, the savings banking sector has seen a merger wave in the last years. When a savings bank faces financial troubles, it is merged with a healthy bank in the neighbourhood. We therefore expect to observe a decrease in capital and an increase in risk for the take-over bank in the year of the merger. In order to capture these effects, we include a merger dummy variable (*MERGER*) in the regression equations, which is unity in the year a savings bank takes over another bank and zero otherwise. Second, as savings banks are the main lenders to local firms, we expect local firm insolvencies to have a negative impact on capital and a positive impact on risk. Hence we approximate these local insolvencies (*INSOLV*) with the ratio of firm insolvencies to the total number of firms in the German state where the savings bank is located. Finally, we also include year dummy variables, which capture further year-specific macroeconomic effects.

Last but not least, we have to find a criterion to distinguish between banks with high capital buffers and banks with low capital buffers. The criterion used by the majority of the literature builds on the capital buffer measured as the absolute difference between the actual Basel capital ratio and the 8% regulatory minimum capital requirement (the “absolute capital buffer”).

In order to test the capital buffer theory, another criterion which is based on the standardised capital buffer is, however, more appropriate. Let us assume the existence of two banks, A and B, both having the same absolute capital buffer. Bank A’s capital buffer is less volatile than Bank B’s capital buffer. Hence Bank A is better insured against a possible violation of the regulatory minimum in spite of both banks holding the same absolute capital buffer. To capture this effect, we divide the absolute capital buffer by the bank-specific standard deviation of the absolute capital buffer (the “standardised capital buffer”). Based on this criterion, we define a regulatory dummy (*REG*), which is unity if a bank has a standardised capital buffer equal to or less than a certain cut-off value and zero otherwise. As cut-off values, we use both the 25 percentile and the median standardised capital buffer. The Sargan (1958) test of overidentifying restrictions indicates, however, that our regressions based on the median capital buffer are not valid. Hence we use the 25% centile in the following. For our sample, this threshold is at 1.6887 standard deviations of the capital buffer above the 8% regulatory minimum.

We test three different effects of the size of the capital buffer on capital and risk adjustments. First, banks with low capital buffers may differ in the magnitude of their capital and risk adjustments from banks with high capital buffers. Hence we include *REG* in the capital and risk equation. Second, we expect that, according to the capital 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, we include *dRISK* and *REG*dRISK* (*dCAP* and *REG*dCAP*) in the capital (risk) equation. And third, we test whether banks with low capital buffers adjust capital and risk faster than banks with high capital buffers. In order to do so, we include $REG*CAP_{t-1}$ ($REG*RISK_{t-1}$) in addition to $CAP_{j,t-1}$ ($RISK_{j,t-1}$) in the capital (risk) equation.

1.4 Specification and hypotheses

In order to obtain the standard form of an endogenous lag model that can be estimated with the software package DPD for Ox (Doornik et al 2002), we add $CAP_{j,t-1}$ and $RISK_{j,t-1}$ to both sides of Eqs. (5) and (6) respectively. With regard to the analysis above, the empirical model is then specified as follows:

$$\begin{aligned} CAP_{j,t} &= \alpha_0 + \alpha_1 REG_{j,t} + \alpha_2 ROA_{j,t} + \alpha_3 SIZE_{j,t} \\ &+ \alpha_4 \Delta RISK_{j,t} + \alpha_5 REG_{j,t} * \Delta RISK_{j,t} + (1-\alpha_6) CAP_{j,t-1} - \alpha_7 REG_{j,t} * CAP_{j,t-1} \\ &+ \alpha_8 MERGER_{j,t} + \alpha_9 INSOLV_{j,t} + \alpha_{10} dy1996 + ... + \alpha_{14} dy2000 + u_{j,t} \end{aligned} \quad (7)$$

$$\begin{aligned} RISK_{j,t} &= \beta_0 + \beta_1 REG_{j,t} + \beta_2 LLOSS_{j,t} + \beta_3 SIZE_{j,t} \\ &+ \beta_4 \Delta CAP_{j,t} + \beta_5 REG_{j,t} * \Delta CAP_{j,t} + (1-\beta_6) RISK_{j,t-1} - \beta_7 REG_{j,t} * RISK_{j,t-1} \\ &+ \beta_8 MERGER_{j,t} + \beta_9 INSOLV_{j,t} + \beta_{10} dy1996 + ... + \beta_{14} dy2000 + w_{j,t} \end{aligned} \quad (8)$$

where $u_{j,t} = \mu_j + \varepsilon_{j,t}$ and $w_{j,t} = \eta_j + \nu_{j,t}$ 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 $\nu_{j,t} \sim IID(0, \sigma_\nu^2)$, independent one another and among themselves.

Taking as the null hypotheses that adjustments in capital and risk do not impact on one another and that the speeds of capital and risk adjustments are equal for banks with high and low capital buffers respectively, we can state our hypotheses in terms of the coefficients as follows:

H_{1a}: $\alpha_4 > 0$ and $\beta_4 > 0$. Adjustments in capital and risk are positively related for banks with high capital buffers as banks with high capital buffers try to maintain their capital buffers. For this hypothesis to hold, it is sufficient that one of the two coefficients is significant.

H_{1b}: $\alpha_4 + \alpha_5 < 0$ and $\beta_4 + \beta_5 < 0$. Adjustments in capital and risk are negatively related for banks with low capital buffers as banks with low capital buffers try to rebuild their capital buffers. For this hypothesis to hold, it is sufficient that one of the two sums is significant.

H_{2a}: $\alpha_7 > 0$. Banks with low capital buffers adjust capital faster than banks with high capital buffers.

H_{2b}: $\beta_7 > 0$. Banks with low capital buffers adjust risk faster than banks with high capital buffers.

3 Data description

The German banking system is highly fragmented and heterogenous. Hence coefficients may not be stable across the different banking groups. To avoid this problem, we try to create a homogenous sample. First, we regard savings banks only. Savings banks are the largest banking group in Germany, representing 36% (48%) of the balance sheet total of all banks (universal banks) (according to the Bundesbank's Banking Statistics). Despite being publicly owned, they aim at maximising profits (Hartmann-Wendels et al 1998). Hence the theories discussed above can indeed be tested on the basis of savings banks. Second, we exclude the central giro institutions from the sample as their portfolio is very different from those of local savings banks.[6] Third, we keep only banks in the sample which remain in existence for at least four years during the observation period. Fourth, we drop the 15 savings banks with capital ratios below 8% as they are under the control of supervisors. And fifth, in order to ensure time series homogeneity, we drop the years 2001 to 2003, which were affected by the burst of the bubble and the ensuing economic downturn.[7] As a result, our sample consists of about 570 local German savings banks over the 1993 – 2000 period, as 1993 was the earliest year for which data on risk-weighted assets were available for savings banks. The balance sheet data were obtained from the Deutsche Bundesbank, which collects bank-level data in its supervisory function. The insolvency data was obtained from the Federal Statistical Office (Statistisches Bundesamt).

Throughout the observation period, the savings banks under review held an average capital buffer of 2.57 standard deviations above the 8% regulatory minimum (see Appendix for some descriptive statistics of the variables).

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6 Private savings banks (so-called free savings banks) are also excluded from the sample as they are not subject to regional investment restrictions and therefore have more degrees of freedom in deciding upon their loan portfolio.

7 The Sargan test is very sensitive to coefficients not being stable over time and therefore indicates valid instruments only when we drop the years 2001 to 2003.

Table 1 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 absolute terms and in standard deviations above the regulatory minimum (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 absence of cross-sectional variation in risk aversion is not surprising.

Table 1: Correlations among variables

	CAP	RISK	dCAP	dRISK	ROA	SIZE	LLOSS	Capital buffer[a]	Capital buffer[b]	INSOLV
CAP	1.0000									
RISK	0.7051	1.0000								
dCAP	0.1466	-0.0601	1.0000							
dRISK	0.0508	0.1208	0.1361	1.0000						
ROA	0.1437	0.1169	0.1356	-0.0006	1.0000					
SIZE	0.0672	0.0703	-0.0587	-0.0317	-0.0696	1.0000				
LLOSS	-0.0906	0.0100	0.0228	-0.0249	-0.3164	0.0593	1.0000			
Capital buffer[a]	0.3273	-0.4153	0.2690	-0.0837	0.0281	0.0044	-0.1181	1.0000		
Capital buffer[b]	0.3660	0.0491	0.0687	-0.0591	-0.0041	-0.0308	-0.1106	0.3881	1.0000	
INSOLV	-0.3908	-0.6025	0.0584	0.0966	-0.1476	0.0236	0.1289	0.3558	0.0091	1.0000

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

4 Methodology and regression results

4.1 Methodology

Unlike previous empirical studies (Shrieves and Dahl 1992; Jacques and Nigro 1997; Aggarwal and Jacques 2001; Rime 2001), 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.[8] The bias will approach zero as T goes to infinity (Nickell 1981). However, in our case, T is relatively small compared to N. To avoid the Nickell bias, we use an instrumental variable approach.

We take the first difference of the model specified in Eq. (7) in order to eliminate the individual effect μ_j, and we try to find suitable instruments for $CAP_{j,t-1} - CAP_{j,t-2}$.[9] 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 could result in seriously biased estimates. Hence we only use a subsample of the whole history of the series as instruments in the subsequent cross-section.[10] Besides, a possible persistence in

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8 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 $\overline{CAP}_{j.-1} = {}_{t=2}^{T} CAP_{j,t-1}/(T-1)$ 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.

9 We use the capital equation as an example in the following. The same considerations in the choice of instruments hold for the risk equation.

10 The Sargan indicates using values of CAP_j and $RISK_j$ lagged two and three times as instruments.

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). Hence we use the system GMM estimator suggested by Blundell and Bond (1998), which uses lagged differences of CAP_j as instruments for equations in levels in addition to the Arellano-Bond instruments.[11]

As, for our sample, the one- and two-step Blundell-Bond system GMM estimators produce quite similar estimates, we present only the (asymptotically) more efficient two-step estimates. However, the two-step estimates of the standard errors tend to be severely downward-biased (Arellano and Bond 1991; Blundell and Bond 1998). To compensate, we use the finite-sample correction to the two-step covariance matrix derived by Windmeijer (2000).

In the case of the risk equation, the Sargan test indicates that we use invalid instruments. We attribute this to the well-known characteristic of the Sargan test to be conservative and we still interpret the estimated coefficients with due caution.

4.2 Regression results

The results of estimating the simultaneous system of Eqs. (7) and (8) are presented in Tables 2 and 3 respectively in addition to the Sargan test and the tests of serial correlation in the first-differenced residuals. Each table contains the result for three different specifications, which vary in the way the regulatory variable affects banks' capital and risk decisions. 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); and, finally,

11 In addition, we also use $LLOSS_j$ and lagged levels of $RISK_j$ 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. In the specifications where we include $REG_j*CAP_{j,t-1}$ and $REG_j*dRISK_{j,t}$ among the regressors, we also use instrumental variables for these interaction terms.

Specification III additionally allows for differences in the coordination of capital and risk adjustments (inclusion of *REG* and *REG*dRISK* and *REG*dCAP*, respectively).

The results show that, as expected, the return on assets (*ROA*) has a statistically highly significant and positive effect on capital. Hence savings banks seem to rely heavily on retained earnings in order to increase capital. However, loan losses (*LLOSS*) show the expected significant and negative effect on risk only in Specification III. Bank size (*SIZE*) has a statistically significant and negative effect on risk, but it seems to have no effect on capital. The negative effect of bank size on risk stands in contrast to most other papers and means that larger banks have lower target risk levels than smaller banks.

The results in Tables 2 and 3 provide also some interesting insights into the impact of capital regulation on the coordination of capital and risk adjustments. The simplest way to model the regulatory impact is to include a regulatory dummy variable, thereby allowing banks with low capital buffers to differ in their capital and risk adjustments by a certain amount from banks with high capital buffers. However, the coefficients of the regulatory dummy are significant only in Specification I, where they have signs opposite to what we expected. The results suggest that banks with low capital buffers increase capital by 0.28 percentage points less and increase risk by 0.65 percentage points more than banks with high capital buffers. This counterintuitive result may be due to the fact that, whereas we measure regulatory pressure in Specification I simply by including a dummy variable, the impact of regulation is actually more complex.

With respect to lagged capital, we estimate and report (1-α_6) instead of α_6. Hence we have to subtract 1 and multiply by -1 in order to obtain the speed of adjustment. The estimated speeds of capital and risk adjustment are highly significant and, in line with the literature, are found to be relatively low. The estimated speed of capital (risk) adjustment lies in the range [0.0761; 0.0922] ([0.0288; 0.0370]), which means that shocks to capital (risk) are halved within 7 and 9 years (18 and 24 years). The very low speed of risk adjustment may be due to the illiquid market for asset-backed securities in Germany, which renders the banks' asset structure rather rigid. In Specifications II to

IV, we additionally allow banks with low capital buffers to adjust capital and risk faster than banks with high capital buffers. With respect to capital, we find that the coefficient of $REG*CAP_{t-1}$ has the expected sign, but is significant in Specification II only. Hence we find mixed evidence that banks with low capital buffers adjust capital faster than banks with high capital buffers. The finding of a higher capital adjustment is in line with the literature (Shrieves and Dahl 1992; Ediz et al 1998; Aggarwal and Jacques 2001). With respect to risk, we find that the coefficient of $REG*RISK_{t-1}$ is not significant, so banks with low capital buffers do not seem to adjust risk faster than banks with high capital buffers.

The coefficient estimates of *dRISK* and *REG*dRISK* in the capital equation are statistically insignificant. Only in Specification I is the coefficient of *dRISK* significantly negative at the 10% level. The coefficient estimates of *dCAP* and *REG*dCAP* in the risk equation become statistically significant once *REG*dCAP* is included in Specification III. For banks with high capital buffers, the coefficient estimate of *dCAP* is positive while, for banks with low capital buffers, the coefficient estimates of *dCAP* and *REG*dCAP* add up to a negative number. 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 high capital buffers do not adjust capital when risk changes. This result is confirmed by a Wald test of the joint significance of the coefficients of *dRISK* and *REG*dRISK*.[12] 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 support our hypotheses H_{1a} and H_{1b}.

We additionally control for take-overs (*MERGER*) and local firm insolvencies (*INSOLV*). Our results suggest that, contrary to our expectations, mergers and local firm insolvencies do not seem to have any effect on capital and risk adjustments. *INSOLV*

12 $Chi^2(2)$ = 2.5722 [0.2763].

has the expected significant and negative sign only in the capital equation in Specification II. Finally, the significance of the year dummy variables indicates the existence of further macroeconomic shocks which are not captured by local firm insolvencies.

Table 2: Blundell-Bond two-step system GMM estimates for $CAP_{j,t}$ (1993-2000)

	I		II		III	
	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value
REG	-0.0028***	-12.30	0.0098	1.51	0.0071	1.01
ROA	0.1660***	2.92	0.2026***	2.80	0.2085***	2.67
SIZE	-0.0001	-1.11	-0.0001	-1.36	-0.0002	-1.62
dRISK	-0.0136	-1.45	-0.0258	-1.29	-0.0220	-1.11
REG*dRISK					-0.0770	-0.94
CAP_{t-1}	0.9078***	70.70	0.9239***	54.70	0.9159***	49.70
$REG*CAP_{t-1}$			-0.2563*	-1.94	-0.1822	-1.20
MERGER	-0.0006	-0.63	-0.0025*	-1.69	-0.0016	-0.95
INSOLV	0.0001	0.36	-0.0002	-0.64	-0.0002	-0.60
dy1996	0.0003	1.13	0.0000	0.12	0.0000	0.13
dy1997	-0.0008***	-3.19	-0.0010***	-3.31	-0.0008**	-2.13
dy1998	-0.0013***	-5.10	-0.0013***	-3.86	-0.0011**	-2.30
dy1999	-0.0013***	-5.02	-0.0014***	-4.08	-0.0011**	-2.45
dy2000	-0.0009***	-2.77	-0.0007	-1.40	-0.0003	-0.40
Intercept	0.0102***	5.26	0.0106***	4.59	0.0117***	4.49
Sargan test	$Chi^2(28)$ = 46.35 [0.016]**		Chi^2 (27) = 31.86 [0.237]		$Chi^2(26)$ = 30.09 [0.264]	
AR(1) test	N(0,1) = -11.06 [0.000]***		N(0,1) = -9.066 [0.000]***		N(0,1) = -8.672 [0.000]***	
AR(2) test	N(0,1) = 0.3189 [0.750]		N(0,1) = -0.7849 [0.433]		N(0,1) = -0.3466 [0.729]	
No of obs (banks)	3380 (574)		3380 (574)		3380 (574)	

Notes: The dependent variable is $CAP_{j,t}$, which is defined as total capital over total assets. *REG* is a dummy variable which is unity if the bank has a standardised capital buffer equal to or less than 1.6887 standard deviations (ie the 25 percentile) and zero otherwise. *ROA* is the return on assets. *SIZE* is defined as the natural log of total assets. *MERGER* is a dummy variable which is unity in the year a bank has taken over another bank and zero otherwise. *INSOLV* is defined as the number of firm insolvencies in the German Federal state where the bank is located over the total number of firms in this state. 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. In addition, we use $LLOSS_j$ and GMM-type instruments of $RISK_j$ as instruments for $dRISK_{j,t}$ in order to account for the simultaneity of capital and risk adjustments. In the specifications where we include $REG_{j,t}*CAP_{j,t}$ and $REG_{j,t}*dRISK_{j,t}$ among the regressors, we also use instrumental variables for these interaction terms. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels 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.

Table3: Blundell-Bond two-step system GMM estimates for $RISK_{j,t}$ (1993-2000)

	I		II		III	
	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value
REG	0.0063***	2.58	-0.0151	-0.93	0.0061	0.27
LLOSS	-0.1394	-0.94	-0.1192	-0.80	-0.2625*	-1.71
SIZE	-0.0022***	-4.42	-0.0022***	-4.34	-0.0017***	-2.82
dCAP	-0.6140	-0.74	-0.5181	-0.62	2.3943*	1.75
REG*dCAP					-9.1397**	-2.54
$RISK_{t-1}$	0.9712***	136.00	0.9630***	105.00	0.9637***	98.40
$REG*RISK_{t-1}$			0.0409	1.31	0.0378	0.96
MERGER	0.0038	0.73	0.0054	1.01	0.0037	0.71
INSOLV	0.0004	0.24	0.0003	0.17	-0.0020	-0.92
dy1996	-0.0069***	-5.05	-0.0070***	-5.04	-0.0076***	-4.90
dy1997	-0.0024	-1.33	-0.0023	-1.27	-0.0007	-0.34
dy1998	0.0056**	2.43	0.0056**	2.45	0.0086***	3.50
dy1999	0.0042*	1.91	0.0044**	1.97	0.0065***	2.89
dy2000	0.0195***	7.85	0.0196***	7.86	0.0225***	8.17
Intercept	0.0677***	5.47	0.0722***	5.63	0.0537***	3.59
Sargan test	$Chi^2(31)$ = 65.41 [0.000]***		Chi2(30) = 63.47 [0.000]***		Chi2(29) = 51.60 [0.006]***	
AR(1) test	N(0,1) = -10.26 [0.000]***		N(0,1) = -10.36 [0.000]***		N(0,1) = -7.020 [0.000]***	
AR(2) test	N(0,1) = -0.7506 [0.453]		N(0,1) = -0.7428 [0.458]		N(0,1) = 0.4215 [0.673]	
Nb. of obs. (banks)	3380 (574)		3380 (574)		3380 (574)	

Notes: The dependent variable is $RISK_{j,t}$, which is defined as total capital over total assets. *REG* is a dummy variable which is unity if the bank has a standardised capital buffer equal to or less than 1.6887 standard deviations (ie the 25 percentile) and zero otherwise. *LLOSS* are defined as new provisions over total assets. *SIZE* is defined as the natural log of total assets. *MERGER* is a dummy variable which is unity in the year a bank has taken over another bank and zero otherwise. *INSOLV* is defined as the number of firm insolvencies in the German Federal state where the bank is located over the total number of firms in this state. Lagged differences of $RISK_j$ are used as instruments for equations in levels, in addition to lagged levels of $RISK_j$ that are used as instruments for equations in first differences. In addition, we use $ROA_{j,t}$ and GMM-type instruments of CAP_j as instruments for $dCAP_{j,t}$ in order to account for the simultaneity of capital and risk adjustments. In the specifications where we include $REG_{j,t}*RISK_{j,t-1}$ and $REG_{j,t}*dCAP_{j,t}$ among the regressors, we also use instrumental variables for these interaction terms. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels 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.

5 Conclusion

Minimum capital requirements play a prominent role in modern banking regulation. A growing branch of the banking literature has dealt with the question of how banks consider capital regulation in their capital and risk decisions. The two major theories in this field are the moral hazard theory and the capital buffer theory (Marcus 1984, Milne and Whalley 2002), which have rivalling predictions for the behaviour of banks. The empirical literature has mainly tested the moral hazard theory. Building on a model developed by Shrieves and Dahl (1992), we are the first to test hypotheses on the relationship between capital and risk adjustments derived from the buffer theory. We further contribute to the literature by using dynamic panel data techniques that explicitly take unobserved heterogeneity into account. And finally, we provide new evidence for non-US banks by using a new dataset of supervisory data collected by the Deutsche Bundesbank.

We find that capital regulation has an impact on capital and risk adjustments in several interesting respects. In line with the literature, we find that banks adjust capital faster than risk. Besides, we find mixed (no) evidence that banks with low capital buffers adjust capital (risk) faster than banks with high capital buffers. With respect to the coordination of capital and risk, we find evidence that banks with low capital buffers attempt to *rebuild* an appropriate capital buffer by decreasing risk when capital decreases. In contrast, banks with high capital buffers attempt to *maintain* their capital buffer by increasing risk when capital increases. However, banks do not adjust capital when risk changes. In summary, our findings are in line with the hypotheses derived from the buffer theory.

6 Appendix

Descriptive statistics

	Mean	Minimum	5 Percentile	Median	95 Percentile	Maximum
dCAP	0.0024	-0.0182	-0.0031	0.0021	0.0090	0.0217
dRISK	0.0087	-0.1155	-0.0274	0.0081	0.0486	0.1606
ROA	0.0026	-0.0204	0.0006	0.0025	0.0050	0.0187
SIZE	20.5974	17.4928	19.0761	20.6176	22.2066	23.7265
LLOSS	0.0034	-0.0213	-0.0008	0.0028	0.0095	0.0410
CAP_{t-1}	0.0541	0.0196	0.0335	0.0547	0.0706	0.1124
$RISK_{t-1}$	0.5303	0.1796	0.3157	0.5514	0.6573	0.7588
MERGER	0.0253	0.0000	0.0000	0.0000	0.0000	1.0000
INSOLV	0.8654	0.4886	0.5038	0.7780	1.8846	2.4551
Capital buffer[a]	0.0262	0.0004	0.0068	0.0225	0.0583	0.1586
Capital buffer[b]	2.5671	0.0334	0.6630	2.5245	4.7106	11.1578

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

Variable means for each year of the observation period

	1994	1995	1996	1997	1998	1999	2000
dCAP	0.0031	0.0027	0.0036	0.0024	0.0016	0.0016	0.0015
dRISK	0.0047	0.0086	-0.0011	0.0036	0.0115	0.0095	0.0252
ROA	0.0029	0.0031	0.0029	0.0026	0.0025	0.0024	0.0022
SIZE	20.3940	20.4783	20.5507	20.6033	20.6602	20.7314	20.7815
LLOSS2	0.0029	0.0043	0.0042	0.0039	0.0035	0.0012	0.0034
CAP_{t-1}	0.0459	0.0490	0.0516	0.0552	0.0576	0.0593	0.0609
$RISK_{t-1}$	0.5150	0.5198	0.5284	0.5272	0.5302	0.5425	0.5509
MERGER	0.0540	0.0366	0.0226	0.0122	0.0070	0.0199	0.0242
INSOLV	0.6510	0.7819	0.8980	0.9513	0.9501	0.8809	0.9516
Capital buffer[a]	0.0147	0.0185	0.0262	0.0303	0.0313	0.0324	0.0301
Capital buffer[b]	1.6812	1.9776	2.6439	2.9595	2.9551	3.0160	2.7698
Nb. of banks	574	574	574	574	568	553	537

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

Variable means for savings banks with low and high capital buffers

	Banks with low capital buffer[a] REG=1	Banks with high capital buffer[b] REG=0
dCAP	0.0019	0.0025
dRISK	0.0102	0.0082
ROA	0.0027	0.0026
SIZE	20.5368	20.6176
LLOSS	0.0040	0.0031
CAP_{t-1}	0.0472	0.0565
$RISK_{t-1}$	0.5184	0.5343
MERGER	0.0435	0.0192
Capital buffer[c]	0.0134	0.0304
Capital buffer[d]	1.0609	3.0688
Nb. of obs.	988	2966

[a] Savings banks with capital buffers lower than 1.6887 standard deviations above the 8% regulatory minimum. – [b] Savings banks with capital buffers higher than 1.6887 standard deviations above the 8% regulatory minimum. – [c]Measured as the Basel capital ratio minus the 8% regulatory minimum. – [d]Measured in standard deviations above the 8% regulatory minimum.

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