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Banks' Regulatory Buffers, Liquidity Networks and Monetary Policy Transmission

by

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Abstract

Based on a quarterly regulatory dataset for German banks from 1999 to 2004, this paper analyzes the effects of banks' regulatory capital on the transmission of monetary policy in a system of liquidity networks. The dynamic panel regression results provide evidence in favor of the bank capital channel theory. Banks holding less regulatory capital and less interbank liquidity react more restrictively to a monetary tightening than their peers.

Keywords: monetary policy transmission, bank lending channel, bank capital channel, liquidity networks

JEL classification: E52, G21, G28, C23

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Non-Technical Summary

The recent theoretical and empirical literature has been giving increasing attention to the role played by banks in the transmission of monetary policy to the real economy. Two possible channels have been discussed. The *bank lending channel theory* argues that small banks with weak liquidity positions have to cut their loan supply after a monetary tightening if the market for *bank debt* is imperfect: Such banks face difficulties in substituting the decrease in deposits by external non-insured funds. In contrast, the *bank capital channel theory* argues that poorly capitalized banks that are subject to capital regulation may cut their loan supply after a monetary tightening if the market for *bank equity* is imperfect: Banks face maturity transformation costs (i.e. costs incurred after a monetary tightening due to the inability to re-price long-term loans, whereas funding turns more expensive immediately), which reduce their interest income and, hence, the capital position. As a consequence, poorly capitalized banks may have to cut lending, thus possibly generating real economic effects if bank customers do not have perfect substitutes for bank loans.

This paper tests whether a bank capital channel type of transmission mechanism exists in the German banking system. The intuition behind the empirical model is the following: banks try to avoid the cost of falling below the regulatory minimum capital requirements by holding capital buffers and asset buffers, i.e. short-term risk-weighted assets (other than customer loans) that can be liquidated if the bank runs into problems with the capital requirement. A monetary tightening leads to costs for banks with a time-to-maturity mismatch between assets and liabilities. Hence, if these banks additionally have low asset and capital buffers, they are expected to react more restrictively, as for them, the expected value of the costs of violating the capital regulation increases.

This paper then tests the derived hypotheses based on quarterly data for German universal banks for the period 1999:03 to 2004:12. We find evidence for the bank capital channel, as banks with a low asset buffer react more restrictively after a monetary tightening than their peers if they face maturity transformation costs. A low regulatory capital buffer has the same effect only in the face of a low asset buffer. All additional pieces of evidence point in the same direction. First, the more pronounced the time-to-maturity mismatch of a bank, the more its income interest position deteriorates. Second, other bank-specific variables that may signal financial strength to market participants and that are often used in the empirical literature to test for the bank lending channel are found to be insignificant. Third, as the majority of German banks is organized in liquidity networks, we also test whether another type of transmission mechanism may come through the respective head institutions. However, we find no evidence to support this hypothesis. All in all, we find clear evidence that a bank capital channel exists in the German banking system.

Nichttechnische Zusammenfassung

Die theoretische und empirische Literatur hat in den letzten Jahren verstärkt die Rolle von Banken in der geldpolitischen Transmission analysiert. Dabei werden zwei mögliche Kanäle diskutiert. Die Theorie des *Bankkreditkanals* argumentiert, dass kleine Banken mit geringer Liquidität bei einer Straffung der Geldpolitik ihre Kreditvergabe einschränken müssen, falls der Markt für Bankschulden unvollkommen ist. Solche Banken können nur schwer den Rückgang der versicherten Einlagen durch die Ausgabe von Schuldverschreibungen kompensieren. Im Gegensatz dazu argumentiert die Theorie des *Bankkapitalkanals*, dass schlecht kapitalisierte Banken, die Mindestkapitalanforderungen einhalten müssen, bei einer Straffung der Geldpolitik ihre Kreditvergabe einschränken müssen, wenn der Markt für Bankkapital unvollkommen ist. Banken entstehen durch steigende Zinszahlungen auf ihre Verbindlichkeiten Kosten, die sie bei längerfristigen Festzinskrediten nicht unmittelbar an ihre Kreditnehmer weitergeben können. Diese Fristentransformationskosten reduzieren das Zinsergebnis und damit das Eigenkapital von Banken. Schlecht kapitalisierte Banken müssen daher ihre Kreditvergabe verringern, was bei fehlenden vollständigen Substituten für Bankkredite einen negativen realwirtschaftlichen Effekt nach sich ziehen kann.

Das Papier testet die Existenz des Bankkapitalkanals in Deutschland. Das empirische Modell nimmt an, dass Banken Kosten der Verletzung der Mindestkapitalanforderungen vermeiden wollen, indem sie Kapitalpuffer und Aktivpuffer (d.h. Aktiva, die bei einer Verschlechterung der Eigenkapitalposition kurzfristig liquidiert werden können) halten. Eine Straffung der Geldpolitik führt zu Fristentransformationskosten, auf die Banken mit niedrigem Kapital- und Aktivpuffer mit einer Einschränkung ihrer Kreditvergabe reagieren müssen, wenn sie eine Verletzung der Mindestkapitalanforderungen vermeiden wollen.

Das Papier testet diese Hypothesen basierend auf Quartalsdaten für deutsche Universalbanken für den Zeitraum von 1999:03 bis 2004:12. Es zeigt sich, dass Banken mit niedrigem Aktivpuffer restriktiver auf eine Straffung der Geldpolitik und damit einhergehende Fristentransformationskosten reagieren als andere Banken. Die gleiche Wirkung hat ein niedriger Kapitalpuffer nur bei gleichzeitigem Vorliegen eines niedrigen Aktivpuffers. Alle zusätzlichen Indizien weisen ebenfalls auf das Vorliegen eines Bankkapitalkanals in Deutschland hin. Zum einen verschlechtert sich das Zinsergebnis von Banken umso mehr, je stärker sie Fristentransformation betreiben. Zum anderen erweisen sich andere bank-spezifische Variablen, die Marktteilnehmern finanzielle Stärke einer Bank signalisieren und die daher in der empirischen Literatur zum Testen des Bankkreditkanals herangezogen werden, als insignifikant. Da die Mehrheit der deutschen Banken in Liquiditätsnetzwerken organisiert ist, überprüfen wir auch, ob der Bankkreditkanal eventuell über die jeweiligen Girozentralen wirken kann. Jedoch können wir dafür keinerlei Indizien finden. Zusammenfassend lässt sich feststellen, dass unsere Ergebnisse auf die Existenz eines Bankkapitalkanals in Deutschland hinweisen.

Contents

1 Introduction

The issue of how monetary policy is transmitted to the real economy remains far from being resolved, although some major theoretical and empirical progress has been made recently.[1] For a long time, most economists did not assign any active role to banks in the transmission of monetary policy. The bank lending channel theory has altered this view, predicting that real economic effects of a monetary tightening are amplified by small banks with weak liquidity positions. If the market for *bank debt* is imperfect, these banks have to cut their loan supply after a monetary tightening. The empirical evidence for the United States indeed shows this pattern (Kashyap and Stein, 2000). But the evidence is at best mixed for Europe in general (Angeloni et al., 2003) and Germany in particular (Worms, 2003).

The difference in the way German and US banks react to changes in monetary policy is related to the structure of the banking system. More than two thirds of German banks are organized in liquidity networks. When the central bank tightens monetary policy, large head institutions inject liquidity into the system, thereby countervailing restrictive effects (Ehrmann and Worms, 2004). Furthermore, a major part of German banks is owned by local authorities and all their liabilities were guaranteed by the government until July 2005. Hence, they faced, at most, lax refinancing constraints.

Recently, a new strand of the literature has given a prominent role to banks and their regulatory capital buffers in monetary policy transmission, even under a frictionless market for bank debt. The bank capital channel theory predicts that banks that are subject to capital regulation may cut their loan supply after a monetary tightening in an imperfect market for *bank equity* (Van den Heuvel, 2002b, 2003). So far, there is no microeconometric evidence on this issue for Germany.[2]

Our paper tests for the existence of the bank capital channel, taking into account the specific features of the German banking system. The idea is that banks try to avoid the cost of falling below the regulatory minimum capital requirements by holding capital buffers and asset buffers, i.e. short-term risk-weighted assets (other than customer loans) that can be liquidated if the bank has trouble complying with the capital requirement. A monetary tightening leads to

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1 For a quite broad but somewhat outdated overview, see Symposium on the Monetary Transmission Mechanism, Mishkin (1995). For European evidence, see Angeloni et al. (2003).

2 For macroeconometric evidence, see Deutsche Bundesbank (2005).

costs for banks, with a time-to-maturity mismatch between assets and liabilities. Hence, if these banks additionally have low asset and capital buffers, they are expected to react more restrictively, as for them, the expected value of the costs of violating the capital regulation increases.

These hypotheses are tested using regulatory bank-level data on German banks. We find evidence that a bank capital channel exists. Banks with a low regulatory capital buffer and a low asset buffer react more restrictively after a monetary tightening than the average bank. This phenomenon can be observed for the whole sample as well as for savings banks and for credit cooperatives, which are both organized in liquidity networks. We have no indication that a low capital buffer of head institutions leads to a more restrictive behavior of the respective liquidity network members.

With respect to the effect of macroeconomic variables on bank lending, we find that a monetary tightening (GDP growth) has the expected negative (positive) effect on bank lending. Interestingly, we detect an omitted variable bias if we do not include a measure of interest rate volatility. Banks are found to lend less in times of volatile interest rates. This is a novel finding for Germany.

The rest of the paper is organized as follows. Section 2 reviews the theoretical literature on the bank capital channel and derives hypotheses. Section 3 presents the empirical model and the methodology. Section 4 gives the empirical results, and Section 5 concludes.

2 Related Literature and Theoretical Hypotheses

According to the bank lending channel theory, monetary policy affects the supply of intermediated credit, particularly bank loans, and is active through an imperfect market for bank debt. A restrictive monetary policy leads to a drop of banks' reservable and typically insured deposits. Only banks that have a larger share of liquid assets or that are bigger are able to shield their lending relationships. The former can draw on their liquid assets, whereas the latter have better access to external finance due to their size. Hence, they do not have to curb their lending as sharply as their small or less liquid peers (see Bernanke and Gertler, 1995). The same may be true for banks with a bigger capital-to-assets ratio: Market participants may perceive highly capitalized banks as being less risky (Kishan and Opiela, 2000). Consequently, it should be more expensive for poorly capitalized banks to finance externally. If debtors do not have perfect substitutes for loans, banks' restrictive lending behavior constitutes a cost to them. As a consequence, the bank lending channel theory predicts a real economic effect in addition to conventional channels, which would not exist under a perfect market for debt.

Empirically, banks with a lower ratio of cash and securities (i.e. liquidity) to total assets react more restrictively to a tightening of monetary policy in the United States (Kashyap and Stein, 2000). The result is attributable to small banks and thus provides evidence in favor of the bank lending channel theory.[3] The evidence for Europe is somewhat mixed and depends very much on the structure of the national banking system.[4] Worms (2003) concluded in an empirical study for Germany that small banks with low liquidity do not necessarily react more restrictively to a monetary policy tightening than their peers. However, banks reduce lending more sharply the lower their ratio of short-term interbank liquidity to total assets. A reaction along the lines of the traditional bank lending channel based on the size criterion can only be found when controlling for the influence of interbank liquidity. Ehrmann and Worms (2004) show in a related paper that German savings banks and credit cooperatives use their head institutions for liquidity management: The head institutions accept short-term deposits from the local banks and provide longer-term loans in return. As a consequence, criteria such as the size of a bank, which would lead to an asymmetric reaction in a banking system without liquidity networks, are partially undone in the German banking system.

In addition, local savings banks and credit cooperatives may not be subject to significantly different costs of finance.[5] As mentioned, most German banks use their head institutions for liquidity management. Even without sufficient short-term deposits at their head institutions, they can re-finance with similar conditions at their head institutions and are thus not subject to a lemon's premium incurred by market participants. This is amplified by the fact that local savings banks and their head institutions enjoyed government guarantees until July 2005 ("*Gewährträgerhaftung*").[6] Besides, for the majority of credit

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3 The result was recently challenged by Baum et al. (2004a). They write that the described pattern is much weaker and thus economically potentially not as relevant when taking market volatility into account. For a theoretical explanation, see Baum (2004b).

4 For a summary of the most recent results, see Angeloni et al. (2003).

5 Differences in the costs of finance depending on bank-specific criteria, however, are necessary in the theoretical model developed by Ehrmann et al. (2003), which was used for a number of empirical studies.

6 Their owners (cities, municipalities, rural districts for savings banks and states plus the local savings banks for the head institutions) guaranteed all liabilities. Thus, in the past, all institutes in the savings bank sector enjoyed the status of a *de facto*

cooperatives and savings banks, the amount of customer deposits is bigger than the amount of overall loans. From 1999 to 2004, this was the case for about 80% of the credit cooperatives and for about 60% of the savings banks in our sample.[7] Thus, these banks have no need for external finance.

At first glance, the empirical finding by Worms (2003) that interbank liquidity matters a lot in Germany seems to contradict our hypothesis. But the bank capital channel theory recently developed by Van den Heuvel (2002b, 2003) sheds a bit more light on this issue. The bank capital channel is active through an imperfect market for bank equity. A restrictive monetary policy directly affects banks via maturity transformation costs, since they typically have a maturity mismatch between assets and liabilities.[8] As a consequence, banks incur losses or make smaller-than-expected profits, affecting their capital. Since it is costly (or almost impossible for most German banks) to raise new equity, banks that are poorly capitalized will have to cut lending to keep an adequate regulatory capital buffer and to reduce the risk of violating the capital requirements.[9] There are three necessary conditions for the bank capital channel to be operative: an imperfect market for bank equity, a maturity mismatch between assets and liabilities exposing banks to interest rate risks, and the existence of minimum capital requirements. All of these conditions are fulfilled in Germany. First of all, locally organized banks are owned either by government institutions or by their members. Hence, it is very difficult for them to raise new equity. But even publicly listed companies are subject to financial frictions. Second, descriptive statistics show that German banks perform maturity transformation (see Appendix C). Finally, all German banks are subject to minimum capital requirements.

Van den Heuvel (2002a) presents indirect evidence that the bank capital channel exists in the United States. When a state's banking sector starts out with a low capital-to-assets ratio, its subsequent output growth is more sensitive to changes to the monetary policy indicator.

Without using regulatory data, it is not clear a priori whether a more restrictive reaction of banks after a monetary tightening is driven by higher costs

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AAA rating (although most of them were not officially rated), and there was no default risk for non-insured liabilities.

7 Measured as time periods when banks had more customer deposits than customer loans. Free savings banks are not included in this number, since they follow different economic dynamics.

8 Loans typically have a longer time to maturity than deposits. Maturity transformation is regarded as one of the main functions of a bank (see e.g. Freixas and Rochet, 2004).

9 According to Basel I, 8% of the loan volume has to be held as capital (there are exceptions for government and other specific loans). A violation of the minimum capital requirement may have serious consequences, such as being taken under the control of the domestic supervisors or even being closed down.

of finance or by the risk of violating the capital requirement. Hence, three studies on European countries (Austria, Italy, and Switzerland) use regulatory data. They do, in fact, find evidence supporting the bank capital channel, as banks with lower regulatory capital buffers[10] are found to react more restrictively to a monetary tightening (Engler et al., 2005; Gambacorta and Mistrulli, 2004; Bichsel and Perrez, 2005).[11]

There is no microeconometric study for Germany so far that uses regulatory capital to analyze the transmission of monetary policy. This paper tries to fill the gap.

3 The Empirical Model and Methods

In this section, we describe our empirical approach. First, we derive our estimation equation and the hypothesis to be tested later in the paper. We subsequently discuss the employed econometric methods.

3.1 Empirical Model

Van den Heuvel (2003) develops a dynamic model that shows that banks' lending response to monetary policy depends on their capital structure. He illustrates in a calibrated model that monetary policy can change the supply of bank loans through its impact on bank equity. However, his model is not suited to derive a reduced form for the reaction of banks to monetary policy depending on their bank-specific criteria and of course does not take into account certain special features of the German banking system, such as liquidity networks.

Hence, in order to test the bank capital channel, we extend the standard model used in the empirical literature (see, for instance, Kashyap and Stein, 2000, Gambacorta and Mistrulli, 2004, and Worms, 2003). The analytical derivations

[10] Some other studies use "excess capital" synonymously for "capital buffer."

[11] Engler et al. (2005) interpret this result in the context of the traditional bank lending channel, since they cannot find any evidence that Austrian savings banks and credit cooperatives perform significant maturity transformation.

can be found in Appendix A and the intuition is described below. Our baseline model has the following dynamic reduced form structure:

$$\begin{aligned}\Delta \ln Loans_{it} &= \sum_{j=1}^{4}\alpha_j \Delta \ln Loans_{it-j} + \beta Capital\,Buffer_{it-1} + \gamma Asset\,Buffer_{it-1} + \delta Risk_{it-1} + \\ &+ \sum_{j=1}^{4}\lambda_j Rho_{it-j}\Delta MP_{t-j} + \sum_{j=1}^{4}\varphi_j Capital\,Buffer_{it-j} Rho_{it-j}\Delta MP_{t-j} + \\ &+ \sum_{j=1}^{4}\omega_j Asset\,Buffer_{it-j} Rho_{it-j}\Delta MP_{t-j} + \sum_{j=1}^{4}\upsilon_j Capital\,Buffer_{it-j} Asset\,Buffer_{it-j} Rho_{it-j}\Delta MP_{t-j} + \\ &+ \sum \tau_t TimeDummies + u_{it}\end{aligned} \tag{1}$$

where Δ is the first-difference operator, *Loans* denotes domestic customer loans (loans to government institutions and financial institutions excluded),[12] *MP* denotes the monetary policy indicator, and *Risk* denotes asset risk. *Rho* is a proxy for the cost a bank incurs when facing a one-percentage-point increase in the monetary policy indicator. Hence, *Rho**Δ*MP* is a proxy for the maturity transformation costs. *i* and *t* refer to the bank and time dimension, respectively. A detailed description of all variables can be found in Appendix B. The error term u_{it} is assumed to consist of a bank-specific component μ_i and white noise ε_{it}. Hence, $u_{it} = \mu_i + \varepsilon_{it}$, where $\mu_i \sim IID(0,\sigma_\mu^2)$, and $\varepsilon_{it} \sim IID(0,\sigma_\varepsilon^2)$, independent of one another and among themselves.

The intuition behind our specification is the following: Banks are monopolistic competitors, which choose an optimal combination of loan interest rate and loan supply, taking the expected costs of falling below the capital requirement and of re-financing into account. Even if banks are not subject to different costs of finance, as in the bank lending channel theory,[13] monetary policy can lead to an asymmetric reaction as predicted by the bank capital channel literature. If a bank faces maturity transformation costs due to an increase in the market interest rate, the risk of violating the capital requirement increases, especially if it is short on its asset and capital buffer. The more short-term risk-weighted assets (other than customer loans) the bank holds on its balance sheet (i.e. the higher the bank's asset buffer), the lower the risk of violating the capital requirements will be: The short-term risk-weighted assets will soon be liquid, thereby reducing the capital requirement in the near future.

12 The change in loans is an approximation for newly issued loans.

13 In the baseline regression we omit the bank lending channel option. In a robustness check, we assume that the amount of inflowing deposits is driven by the stance of monetary policy to incorporate the features of the bank lending channel into the model. As a consequence, monetary policy can be transmitted via the head institution of the liquidity network of banks.

Also, the higher the bank's capital buffer, the lower the risk of violating the capital requirement will be. If the asset and capital buffer are not sufficiently high, given maturity transformation costs the bank faces a higher risk of violating the capital regulation after a monetary tightening. Thus, it may decide to cut its loan supply by more than its peers in order to restore adequate capital and asset buffers. Even if banks are not pure profit maximizers, they will weigh the risk of violating the capital requirements against other objectives, such as relationship banking.

The empirical specification is very similar in spirit to Worms (2003), who uses an interaction between different bank-specific variables and the money market rate to test for the bank lending channel. We deviate in two ways from his specification. First of all, we use the capital buffer instead of the capital-to-assets-ratio, since we consider the distance from the regulatory threshold as the relevant criterion for the bank capital channel. Second, the bank-specific variables are not interacted with the market interest rate, but with the proxy for maturity transformation costs ($Rho*\Delta MP$), as low buffers will only affect a bank according to the bank capital channel theory if it faces maturity transformation costs.[14] In Appendix B, it can be seen that almost all German banks have a longer time-to-maturity of assets than liabilities, i.e. they have a positive *Rho*. Thus, the bigger *Rho*, the more exposed is a bank to interest rate increases, and the more pronounced should be its reaction in terms of loan volume reduction.

We consider the double interaction of the asset and capital buffer as very important, since it captures the interaction between both variables, i.e. it conditions one on the other. Intuitively, a bank should be very cautious if it is low on both types of buffers, whereas having either a significantly high asset or capital buffer may reduce the risk of violating the capital requirements significantly.

As we do not know the right set of macro variables in advance and as there is always the danger of not capturing the time effects properly and thus obtaining seriously biased coefficients for the micro variables, we replace all macro variables in the baseline regression with a set of time dummies. This comes with a price tag: we do not know how the average bank will react to interest rate changes and other macro variables. To overcome this problem, we experiment later to find out which set of macro variables leads to similar estimated coefficients for the micro variables.

To capture the dynamics fully, we add lags to explanatory variables. Furthermore, we add the asset and capital buffer as level terms to keep our estimated specification as general as possible and to prevent an omitted variables bias.

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[14] Furthermore, this paper uses the observation period 1999-2004 (post European Monetary Union period), whereas Worms (2003) uses the time span 1992-1998.

For expositional simplicity, we do not show the full (short-term) dynamics when giving the regression results in Section 4 but instead confine ourselves to showing the "long-term" coefficients. For instance, we calculate the "long-term" coefficient λ using the following formula:

$$\lambda = \sum_{j=1}^{4} \lambda_j / (1 - \sum_{j=1}^{4} \alpha_j) .$$

The other "long-term" coefficients are calculated accordingly.

Taking as the null hypothesis that German banks do not react along the lines of the bank capital channel, we can state our hypothesis in terms of the coefficients φ, ω, and υ as follows:[15]

$$H_1: \varphi > 0, \text{ or } \omega > 0, \text{ or } \upsilon < 0$$

We expect banks with a lower capital buffer to react more restrictively if they face maturity transformation costs (φ>0) caused by a monetary tightening. Similarly, we expect the same for banks with a lower asset buffer (ω>0). Finally, we expect that banks that are weak in both categories are at a disproportionately high risk of running into trouble with the capital regulation. We therefore expect them to react much more restrictively (υ<0). For the capital channel to be at work, at least one of these three estimated long-term coefficients has to show the expected significant sign and none of the other coefficients may show an unexpected significant sign. For the double interaction term (υ<0), it is important to know whether it is driven by banks with low or high capital and asset buffers. The latter would lead to the counterintuitive result that banks with high asset and capital buffers react more restrictively to a monetary tightening than their peers. This will be analyzed in a robustness check.

In the following analysis, we use two measures of banks' asset buffers. The first measure contains short-term interbank assets with a maturity of up to one year, whereas the second one additionally includes shares and securities holdings. While short-term interbank assets are not subject to interest rate risk, securities and shares may suffer significant losses if the interest rate increases. These losses may prevent sales, which means that the first measure therefore contains more highly liquid assets than the second measure.

Further, short-term interbank loans may serve a double function. Local banks deposit short-term funds at their respective head institutions in the liquidity network and obtain long-term loans in return (Ehrmann and Worms, 2004). Thus, the more short term loans a bank holds at the interbank market, the less it is exposed to maturity transformation costs. Hence, banks can use this instrument

15 Please note that *Capital Buffer* and *Asset Buffer* are demeaned and hence take on negative values for banks with low buffers (see Appendix A for details).

as a hedging mechanism. This, in turn, also reduces the risk of violating the capital requirements.

The question as to whether a potential differential reaction of banks to monetary policy based on the first asset buffer (short-term interbank loans) is driven more by the described asset buffer function or by its hedging characteristics goes beyond the scope of this study. As a consequence, we stay agnostic in what follows and call the first asset buffer interbank liquidity, thus leaving this question to the critical reader and future research.

3.2 Econometric Approach

Given Eq. (1), we employ dynamic panel data techniques that control for the bank-specific effects μ_i. We take the first difference of the model specified in Eq. (1) in order to eliminate the individual effect μ_i, and we try to find suitable instruments for the lagged endogenous variable. Arellano and Bond (1991) suggest a generalized method of moments (GMM) estimator that uses the entire set of lagged values of the endogenous variable as instruments. Arellano and Bover (1995) and Blundell and Bond (1998) show that additional moment conditions are valid if the autoregressive process is mean-stationary: then, first differences of the endogenous variable are uncorrelated with the individual effect μ_i and can thus be used as instruments for equations in levels. In order to obtain the efficient GMM estimator, both sets of moment conditions have to be combined to obtain the "system GMM estimator" proposed by Blundell and Bond (1998). Given the potential endogeneity of the other bank-specific variables, *Capital Buffer* and *Asset Buffer*, we also include GMM-style instruments for these variables. We only use a sub-sample of the whole history of the series as instruments in the later cross-section. To determine the optimal lag length of the instruments, we use the Hansen test as the specification criterion (Andrews and Lu, 2001).

As, for our sample, the one- and two-step Blundell-Bond system GMM estimator 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 (2005).

Since the econometric literature has pointed out that GMM estimations may deliver inconsistent results too (see e.g. Bound and Baker, 1993), Appendix D additionally shows results from fixed effects regressions as a robustness check. Alvarez and Arellano (2003) find that the GMM estimates are close to fixed effect estimates for panels with a large time dimension.[16] We therefore expect the two methodologies to yield qualitatively similar results.

4 Empirical Results

Our dataset consists of bank-level confidential supervisory data on German universal banks (commercial banks, savings banks with their central giro institutions, and credit cooperatives with their central giro institutions) for the time period 1999:03 to 2004:12 (following the establishment of the European Monetary Union). The variable definition and the treatment of outliers and mergers are described in full detail in Appendix B.

In the following subsections, we first present the results of estimating Eq. (1). We then give additional evidence that the results are indeed in line with the capital channel. Finally, we show that our results may also be economically significant.

4.1 Asymmetrical Reactions to Monetary Policy

Baseline Regression

Table 1 shows the long-term coefficients obtained from estimating Eq. (1) and the specification tests (Hansen test and the tests of serial correlation in the first-differenced residuals). Since the results obtained from fixed effects are qualitatively the same and differ only in magnitude (see Table A3 in Appendix D), we confine ourselves to discussing the results obtained from the Blundell-Bond procedure, unless we consider differences to be insightful.

First, in the baseline regression with time dummies, the estimated coefficient for the interaction term of *Interbank Liquidity* and *Maturity Transformation*

16 Like the GMM estimator, the fixed effects estimator also wipes out the μ_i. However, it is still biased of $O(1/T)$, and its consistency depends on T being large (Nickell 1981). In our case, T is about 20 and, hence, larger than in most panel datasets. We therefore opt to complement our GMM estimates with fixed effects estimates.

Costs is found to be significant and positive, while the interaction term between *Capital Buffer* and *Maturity Transformation Costs* is found to be insignificant. This means that banks with below-average interbank liquidity react in a more strongly negative way to a monetary tightening than their average peers, which gives support to hypothesis H_1.

Second, the interaction term between *Capital Buffer, Interbank Liquidity,* and *Maturity Transformation Costs* is found to be significant and negative. This indicates that there is a meaningful interaction between the interbank liquidity and the capital buffer. Banks with both a low capital buffer and low interbank liquidity react more restrictively to an increase in the interest rate than their peers which have, for instance, only a low interbank liquidity, thus giving support to hypothesis H_1: The lower the capital buffer and the interbank liquidity, the higher the risk they face of violating the capital requirements. As a consequence, banks with a low capital buffer and low interbank liquidity act more restrictively than their average peers when they face maturity transformation costs after a monetary tightening.

The sign of the estimated coefficient of the interaction term of *Capital Buffer, Interbank Liquidity,* and *Maturity Transformation Costs* may also indicate that highly capitalized banks with an above-average asset buffer also react more restrictively to an increase in the interest rate (due to the normalization). This last effect would clearly be counterintuitive. Hence, in the following subsection, we analyze whether the significant and negative sign of the coefficient is driven by highly or poorly capitalized banks. To do so, we assign dummies according to their average capitalization in the next section.

Table 1: Long-Term Coefficients for Estimating Eq. (1)—Blundell-Bond

Dependent Variable: *Loan Growth*	(1) Baseline Without Macro Variables	(2) Baseline With Macro Variables
Risk	-4.57***	-4.65***
	(-13.48)	(-11.60)
Capital Buffer	-0.03	-0.02
	(-1.16)	(-0.80)
Interbank Liquidity (IL)	0.00	0.00
	(0.70)	(0.06)
*Capital Buffer*Rho*ΔMP*	0.20	-0.16
	(0.32)	(-0.20)
*IL * Rho * ΔMP*	0.39**	0.27
	(2.30)	(1.33)
*Capital Buffer * IL* Rho * ΔMP*	-0.43***	-0.46***
	(-3.01)	(-2.70)
*Rho * ΔMP*	-1.74	-4.39
	(-0.82)	(-0.78)
ΔMP		-0.47
		(-0.62)
GDP Growth		1.86***
		(8.83)
Time Dummies	Yes	No
# Obs. (Banks)	26666 (2263)	26666 (2263)
Hansen Test	1.000	0.000***
AR(1)	0.000***	0.000***
AR(2)	0.825	0.909

Notes: The table gives the long-term coefficients based on Blundell-Bond two-step estimations with Windmeijer corrections of Eq. (1). The dependent variable is *Loan Growth*, measured as the quarterly growth rate of domestic loans to non-financial firms and to private customers. *Risk* is defined as new loan loss provisions plus loan write-offs divided by total loans. *Capital Buffer* is defined as regulatory capital minus risk-weighted assets divided by total assets. *Asset Buffer* is defined as short-term interbank claims divided by total assets. *Rho* is a proxy for the maturity transformation cost a bank faces after a one-percentage-point increase in the monetary policy indicator. Δ*MP* is defined as the absolute change in the three-month EURIBOR (=monetary policy indicator). *GDP Growth* is defined as quarterly growth rate of real GDP. For better readability of the table, the estimated coefficients for *Rho* ΔMP* are rescaled by the factor 10^{-2}, *Capital Buffer * Rho** Δ*MP* and *Interbank Liquidity * Rho ** Δ*MP* by 10^{-4} and *Capital Buffer * Interbank Liquidity * Rho** Δ*MP* by 10^{-6}. t-statistics are given in brackets. ***, **, and * indicate statistical significance at the 1, 5, and 10 percent levels, respectively, in a two-tailed *t*-test. Hansen test refers to the test of overidentifying restrictions. AR(1) and AR(2) test refer to the test for the null of no first-order and second-order autocorrelation in the first-differenced residuals. For the Hansen, the AR(1), and the AR(2) tests, p-values are shown.

If we use the quarterly changes of the Euribor and the real GDP growth rate instead of the full set of time dummies, we obtain similar results for the interaction term of *Capital Buffer, Interbank Liquidity,* and *Maturity Transformation Cost*. But the significant coefficient for the interaction term of *Interbank Liquidity* and *Maturity Transformation Costs* cannot be replicated. As expected, lending depends positively on real GDP growth. The estimated coefficient for interest rate changes is negative, but surprisingly not significant.

The described results and the rejection of the Hansen test (although the autocorrelation tests of second and higher order show no problems) indicate that the two macro variables are unable to capture the time effects entirely and/or we have chosen an inappropriate set of instruments. This issue will be discussed in more detail in the dummy approach in the next section.

If we use the second asset buffer measure (instead of interbank liquidity), which also includes securities and shares, we find no evidence throughout the entire sample that banks react asymmetrically with respect to this measure. Interestingly, if we split the sample according to banking groups (not shown here), for savings banks, the second asset buffer measure delivers estimation results that are qualitatively similar to those for interbank liquidity. The estimated coefficient for the interaction term of *Capital Buffer, Asset Buffer 2,* and *Maturity Transformation Costs* is negative and significant at the 5% level. The critical reader may wonder if this result is driven by the interbank liquidity, which is also contained in this measure. But the correlation between the two asset buffers is only 0.23 in the savings bank sector. Since we do not find similar patterns in the subsample for credit cooperatives or the entire sample, we leave this issue for future micro banking research and concentrate on the first asset buffer (interbank liquidity) in what follows.

There are two possible explanations why the interbank liquidity performs far better in the overall sample: First, shares and securities are subject to interest rate risk and may thus not be sufficiently liquid to serve as an asset buffer. When banks face maturity transformation costs after a monetary tightening, these assets' value may deteriorate. Alternatively, the additional hedging function of interbank liquidity, as described in Section 3, might render them more important.

The estimated coefficient for *Maturity Transformation Costs* is insignificant in Specifications (1) and (2), indicating that banks do not react to maturity transformation costs as such, but only in interaction with the asset and capital buffer. This result is in line with our theoretical setting. Although maturity transformation costs reduce the current profit of a bank, they are sunk costs. Their current magnitude is determined by the term structure of assets and liabilities one period before, which cannot be affected by the contemporary loan policy. Thus, banks only react more restrictively to maturity transformation costs if they belong to the group of poorly capitalized and low liquidized banks.

The baseline regression furthermore shows that, higher *Risk* leads to a significant decrease in loan growth: As increasing credit risk increases the need to build up capital buffers, banks with a more risky loan portfolio have a slower loan growth.

Neither the capital buffer nor the interbank liquidity shows a significant influence on the average loan growth in our sample. Interestingly, the fixed effect regressions indicate that banks with a bigger asset or capital buffer have a faster loan growth.

Dummies

In order to see whether the significant negative coefficient of the interaction term of *Capital Buffer, Interbank Liquidity,* and *Maturity Transformation Costs* we have detected is driven by banks with high or low capital buffers, we define dummy variables that capture the capitalization of banks. We assign one dummy to banks that are, on average, below the 50th percentile of excess capitalization (*Low*) and one dummy to those banks above this threshold (*High*).[17] Each dummy is multiplied by the interaction term of interbank liquidity and maturity transformation costs. This allows us to disentangle the effects in the full specification and to assign them to poorly and well capitalized banks. We are aware that the threshold is arbitrary and therefore check to see whether the results depend on the chosen threshold.[18]

$$\begin{aligned}
\Delta \ln Loans_{it} &= \sum_{j=1}^{4} \alpha_j \Delta \ln Loans_{it-j} + \gamma_1 Low_i Asset\,Buffer_{it-1} + \gamma_1 High_i Asset\,Buffer_{it-1} + \delta Risk_{it-1} + \\
&+ \sum_{j=1}^{4} \lambda_{1j} Low_i Rho_{it-j} \Delta MP_{t-j} + \sum_{j=1}^{4} \lambda_{2j} High_i Rho_{it-j} \Delta MP_{t-j} + \\
&+ \sum_{j=1}^{4} \omega_{1j} Low_i Asset\,Buffer_{it-j} Rho_{it-j} \Delta MP_{t-j} + \sum_{j=1}^{4} \omega_{2j} High_i Asset\,Buffer_{it-j} Rho_{it-j} \Delta MP_{t-j} + \\
&+ \sum \tau_t TimeDummies + u_{it}
\end{aligned} \tag{2}$$

Table 2 shows the regression results for Eq. (2). Like the baseline regression, higher *Risk* is found to lead to a significant decrease in loan growth. Further, the interaction term between *Interbank Liquidity* and *Maturity Transformation Costs* corresponds to the interaction term between *Capital Buffer, Interbank Liquidity,* and *Maturity Transformation Costs* in the baseline specification shown in

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17 Without previously normalizing excess capital to zero, the sample split for credit cooperatives and savings banks delivers similar results.

18 To check for robustness, we validated all results obtained from the dummy approach by using an equivalent sample split for poorly and highly capitalized banks, which is somewhat less restrictive with respect to the imposed dynamics (for instance, not assigning the same estimated coefficients for the lagged dependent variable for both types of banks). Since this approach leads to the same conclusions, we do not show the estimated coefficients.

Table 1. The regression results show that the interaction term between *Interbank Liquidity* and *Maturity Transformation Costs* is significant and positive only for poorly capitalized banks and insignificant for well capitalized banks. Hence, poorly capitalized banks react more restrictively to an increase in maturity transformation costs if they have below-average interbank liquidity.

However, the reaction of highly capitalized banks to a change in the interest rate does not depend on interbank liquidity. Again, these findings support the hypothesis that the asset buffer plays an important role in interaction with the capital buffer, namely for poorly capitalized banks.

As a robustness check, we run the same exercise and assign one dummy to the lowest capitalized 25% of banks, one to banks capitalized within the 25% to 75% range, and a third to the highest capitalized 25% of banks. The estimated coefficient for the lowest capitalized banks is positive and significant at the 5% level, while banks in the middle range show a positive, albeit insignificant sign, and the best capitalized banks a negative and insignificant sign. This confirms that the asymmetry is driven by the lowest capitalized banks in interaction with their interbank liquidity.

If we replace the time dummy specification with a set of macro variables, the quarterly changes in the Euribor and the real growth rate of GDP, we obtain the same qualitative results for the interaction terms, thus confirming the aforementioned hypotheses. As expected, the reaction to real GDP growth is highly significant and positive, thus capturing loan demand effects. As in the baseline specification, the estimated long-run coefficient for interest rate changes is insignificant.

However, the implausible insignificance of ΔMP disappears if we include a volatility measure for the monetary policy indicator (calculated based on daily data; see Appendix B for details) into the regression, as suggested by Baum (2004a, b). As a consequence, the estimated coefficient for ΔMP gains significance and increases in magnitude. The latter also holds for the estimated GDP coefficient. The volatility measure itself is found to be highly significant and negative, indicating that higher interest rate volatility results in lower lending activity on average. The big changes in the estimated coefficients for the other two macroeconomic variables show that Specification (2), which only includes real GDP growth and interest rate changes instead of the full set of time dummies, suffers from a severe omitted variable bias.

Baum et al. (2004b) argue that banks behave more homogenously during times of greater macroeconomic uncertainty, since macroeconomic volatility prevents them from foreseeing investment opportunities. The inclusion of macroeconomic volatility by Baum et al. (2004a) weakens the results in favor of the bank lending channel, which was assembled by Kashyap and Stein (2000) for the United States.

Table 2: Long-Term Coefficients for Estimating Eq. (2)—Blundell-Bond

Dependent Variable: *Loan Growth*	(1) Dummies Without Macro Variables	(2) Dummies With Macro Variables	(3) Dummies With Macro Variables (incl. Volatility)
Risk	-4.31***	-4.58***	-4.38***
	(-13.15)	(-11.80)	(-11.43)
*Interbank Liquidity (IL)*Low*	-0.01	-0.01	-0.04
	(-1.09)	(-0.96)	(-1.73)
*Interbank Liquidity*High*	0.01	0.00	-0.01
	(1.49)	(0.21)	(-0.74)
*IL*Volatility*Low*			0.18
			(1.44)
*IL*Volatility*High*			0.09
			(0.73)
*IL*Rho*ΔMP*Low*	0.56**	0.75**	0.77**
	(2.09)	(2.10)	(2.36)
*IL*Rho*ΔMP*High*	0.02	0.01	-0.09
	(0.07)	(0.02)	(-0.31)
*Rho*ΔMP*Low*	-2.77	-2.83	-8.44
	(-0.96)	(-0.41)	(-1.36)
*Rho*ΔMP*High*	-4.29	-5.49	-10.37
	(-1.59)	(-0.83)	(-1.70)
ΔMP		-0.42	-2.01**
		(-0.47)	(-2.26)
GDP Growth		1.74***	4.36***
		(8.14)	(10.54)
Volatility			-4.63***
			(-6.35)
Time Dummies	Yes	No	No
# Obs. (Banks)	26671 (2263)	26671 (2263)	26671 (2263)
Hansen Test	1.000	0.255	1.000
AR(1)	0.000***	0.000***	0.000***
AR(2)	0.882	0.658	0.575

Notes: The table gives the long-term coefficients based on Blundell-Bond two-step estimations with Windmeijer corrections of Eq. (2). Volatility is measured as intra-quarterly volatility of the three-month EURIBOR based on daily data. For the other variable definitions, see Table 1. To improve the readability of the table, the estimated coefficients for *Rho**ΔMP* are rescaled by the factor 10^{-2}, *Capital Buffer*Rho* ΔMP* and *Interbank Liquidity*Rho*ΔMP* by 10^{-4}, *Capital Buffer*Interbank Liquidity*Rho*ΔMP* by 10^{-6}, *Volatility* by 10^{4}, and *Interbank Liquidity*Volatility* by 10^{2}. t-statistics are given in brackets. For savings banks, we use only three lags of the endogenous variables, since this is sufficient to capture the dynamics. ***, **, and * indicate statistical significance at the 1, 5, and 10 percent levels, respectively, in a two-tailed *t*-test. Hansen test refers to the test of overidentifying restrictions. AR(1) and AR(2) test refer to the test for the null of no first-order and second-order autocorrelation in the first-differenced residuals. For the Hansen, the AR(1), and the AR(2) tests, p-values are shown.

Unlike in Baum (2004a), the finding that banks react asymmetrically to interest rate changes (expressed by the interaction terms of *Interbank Liquidity* and *Maturity Transformation Costs*) remains unaffected by the inclusion of the volatility measure. The estimated coefficient for the interaction term remains similar, whereas the magnitude and significance level even increase somewhat in the Blundell-Bond estimation. Furthermore, the estimated coefficient for the interaction term of *Volatility* and *Interbank Liquidity* is insignificant.

Thus, interestingly, German banks do not seem to be affected by Baum's critique that the result of an asymmetric reaction of banks to monetary policy is weakened or even undone by including second moments. We hypothesize that his point may be more relevant to the bank lending channel than to the bank capital channel. We would tend to expect poorly capitalized banks to act more cautiously if they cannot foresee investment opportunities properly.

All in all, the dummy approach underlines the hypothesis that banks with a low capital buffer and a low interbank liquidity react more restrictively to monetary policy than the average bank.

4.2 Further Evidence

In this subsection, we present several pieces of evidence that lend additional support to our finding in favor of the bank capital channel. First, we analyze whether maturity transformation costs, as defined by our proxy (see Appendix B), are able to influence the interest income of banks significantly. This is an important precondition for the bank capital channel to be active. Second, we check to see if the asymmetric reaction is driven by a bank lending channel-type mechanism. Therefore, we check (i) to see if banks react differently depending on the customer deposits relative to customer loans on their balance sheet and (ii) if savings banks, which are organized in liquidity networks, react asymmetrically depending on the bank-specific criteria of their respective head institution.

Interest Income

The bank capital channel theory argues that a monetary tightening reduces bank profits, as banks face maturity transformation costs. Thus, poorly capitalized banks have to reduce lending, as they see their capital position deteriorating even further or are not able to reestablish a sustainable capital buffer. Hence, a necessary precondition for the bank capital channel to be at work is deteriorating profits after a monetary tightening. We test this precondition by regressing banks' interest income on their maturity transformation costs. As interest income is available only on a yearly basis, we use a yearly dataset in this subsection (see Table 3 for results).

Specification 1 shows that maturity transformation costs have a highly significant effect on interest income. As we do not include control variables other than time dummies, it is particularly important to rule out autocorrelation in the error term. However, if we allow for an AR(1) process in the error term (Specification 2) or include lagged interest income in the fixed effects estimation (Specification 3) or Blundell-Bond estimation (not shown here), the result is qualitatively unaffected.

In sum, banks are found to face maturity transformation costs after a monetary tightening that reduces their interest income. The existence of this precondition for the bank capital channel to be at work strongly supports our argument that the detected decline in bank lending by poorly capitalized banks after a monetary tightening is indeed due to the bank capital channel.

Table 3: Fixed-Effects Estimations, 1999-2004

	(1)	(2)	(3)
Dependent Variable: *Interest Income$_t$*	Robust Standard Errors	AR(1) Standard Errors	Robust Standard Errors
Interest Income$_{t-1}$			-0.00
			(0.09)
Rho_t ΔMP_t*	-0.35	-0.18*	-0.35
	(1.31)	(1.84)	(1.31)
Rho_{t-1} ΔMP_{t-1}*	-1.14***	-0.56***	-1.14***
	(4.61)	(5.84)	(4.61)
Constant	0.05***	-0.01***	0.05***
	(117.88)	(4.07)	(117.87)
Time Dummies	Yes	Yes	Yes
# Obs. (Banks)	11877 (2742)	9135 (2432)	11877 (2742)

Notes: The table gives the coefficients based on fixed effects estimation. The dependent variable is *Net Interest Income*, measured as net interest income divided by the average of fixed-interest-bearing assets and liabilities. *Rho* is a proxy for the maturity transformation cost a bank faces after a one-percentage-point increase in the monetary policy indicator. ΔMP_i is defined as the absolute change in the three-month EURIBOR (=monetary policy indicator). ***, **, and * indicate statistical significance at the 1, 5, and 10 percent levels, respectively, in a two-tailed *t*-test.

Network Effects for Savings Banks?

There is an alternative possible way of transmission. It is possible that the members of a liquidity network will restrict lending after a monetary tightening if their respective head institution begins to have trouble providing sufficient liquidity. To test this hypothesis, we have to match the banks with their respective head institution and analyze whether member banks react differently depending on the head institutions' bank-specific criteria. However, for credit cooperatives, such an assignment does not exist, as they can re-finance at both of their head institutions. In contrast, for savings banks, there is a strict regional system for assigning local savings banks to their head institutions. We therefore analyze this hypothesis for savings banks only.

Since the head institutions of savings banks were subject to *Gewährträgerhaftung* (publicly underwritten liability) during our sample period, they were considered as AAA-rated banks and should not have run into trouble to acquire sufficient sources of finance. However, they could have reacted more restrictively because of the expected cost of violating the capital rules. Thus, in addition to the standard specification above, we interact the monetary policy indicator with the excess capital position of the respective head institution:

$$
\begin{aligned}
\Delta \ln Loans_{it} = {} & \sum_{j=1}^{4} \alpha_j \Delta \ln Loans_{it-j} + \beta Capital\,Buffer_{it-1} + \gamma Asset\,Buffer_{it-1} + \delta Risk_{it-1} + \\
& + \sum_{j=1}^{4} \lambda_j Rho_{it-j} \Delta MP_{t-j} + \sum_{j=1}^{4} \varphi_j Capital\,Buffer_{it-j} Rho_{it-j} \Delta MP_{t-j} + \\
& + \sum_{j=1}^{4} \omega_j Asset\,Buffer_{it-j} Rho_{it-j} \Delta MP_{t-j} + \sum_{j=1}^{4} \upsilon_j Capital\,Buffer_{it-j} Asset\,Buffer_{it-j} Rho_{it-j} \Delta MP_{t-j} + \\
& + \sum_{j=1}^{4} \vartheta_j Capital\,Buffer_{head\,of\,i,t-j} Rho_{head\,of\,i,t-j} \Delta MP_{t-j} + \sum \tau_t TimeDummies + u_{it}
\end{aligned}
\qquad (4)
$$

The estimated long-run coefficient of the interaction between excess capital and monetary policy indicator is found to be insignificant. As a consequence, we conclude that there are no signs that local savings banks were credit constrained by their head institutions.[19]

Bank Lending Channel

The critical reader may wonder whether the differences in the banks' reaction with respect to their excess capitalization and interbank liquidity were driven by

19 Interestingly, the estimated coefficient of the second and third lag of the interaction term was highly significant. This may be an indication that the bank-specific variables of the head institutions have an effect on the members of the respective network.

the bank *lending* channel rather than the bank *capital* channel. The reasoning could go as follows: highly capitalized banks may find cheaper sources of unsecured finance than their poorly capitalized peers since market participants perceive them as less risky. Furthermore, interbank liquidity may be used to shelter customer loans when deposits are withdrawn.

Yet, the theoretical literature has — so far — failed to provide a consistent framework to test the bank capital channel against the bank lending channel. In their empirical paper, Gambacorta and Mistrulli (2004) argue that the capital buffer captures the bank lending channel, while the maturity transformation costs capture the bank capital channel. This line of argument is not fully convincing, as the bank capital channel works through the interaction of maturity transformation costs and capital. However, as the variables used to test the two channels are either identical or at least highly correlated, an empirical approach that separates the two channels is hard to come by. We are still convinced that our results are driven by the bank capital channel due to the following reasons.

First, as mentioned in Section 2, a large percentage of German savings banks and credit cooperatives have a much larger amount of customer deposits than loans. For those banks, the traditional bank lending channel may not be strongly operative since a drop in deposits after a monetary tightening would not automatically force them to seek external sources of finance.[20] If we restrict our sample to periods where banks have more deposits than loans on the balance sheet, we can find the same asymmetric pattern as for the entire sample. This gives us a further indication that the asymmetric reaction is driven by the bank capital channel.

Second, other bank-specific criteria that are usually used to test for the bank lending channel are less significant, or not significant at all. Interestingly, if we specify the model without maturity transformation costs, we obtain a qualitatively similar pattern as before (results are not shown here, but are available on request). However, if we specify our baseline equation with cash to overall assets instead of interbank liquidity and the capital-to-assets ratio instead of the excess capital, none of the estimated coefficients for the interaction terms is significant at conventional levels. Further, if we define a *Liquidity* variable that includes all assets with a maturity shorter than one year and securities (unlike the second asset buffer, this measure also includes other positions such as cash), and interact it with *Excess Capital*, we cannot obtain a significant estimated coefficient. These findings do not necessarily mean that the bank *lending* channel does not exist. Yet, they lend further support to our hypothesis that the bank *capital* channel is at work.

20 Yet, although banks with more deposits than loans can, in principle, shelter their customer loan supply after a monetary tightening, they may want to protect their other investments due to portfolio considerations and, hence, may cut lending.

Summary
The additional evidence provided in this subsection gives support to the hypothesis that the asymmetric reaction that we observe is indeed due to the bank capital channel, although we do not rule out the possibility that the bank lending channel may exist in parallel and thus strengthen the observed pattern. Furthermore, there appears to be no indirect transmission via poor capitalization of the head institutions in the savings bank sector.

4.3 Should We Care?

Ashcraft (2006) asks the question: "Bank loans might be special, but should macroeconomists care?" Microeconometric evidence can only provide a first indication of whether the bank capital channel can possibly affect the macro economy. This is only the case if loan supply movements are large enough to influence business cycle fluctuations.

Therefore, we analyze the size of poorly capitalized banks.[21] In terms of loan volume (assets), they are, on average, about 2.5 (3) times bigger than their well-capitalized peers (see Appendix C). Thus, in contrast to many studies for the bank lending channel,[22] the asymmetric reaction of banks is not only driven by very small banks, which are potentially irrelevant to the macro economy.

The regression results indicate that banks with a weak interbank liquidity position and a high exposure to maturity transformation costs, behave most restrictively. For simplicity, we assume that the 50 percent of banks with the lowest interbank-liquidity buffer and with the largest exposure to maturity transformation costs are well represented by the 25th percentile within this subsample. Using the estimated coefficients, these banks would react by an average of around 0.2 percentage point more restrictively than the average bank if we take the most conservative GMM estimation and about 0.1 percentage point if we use the fixed effects results.[23]

After a monetary contraction, following our regression results, we would expect those banks that have the most negative values in the interaction of de-meaned interbank liquidity and the most pronounced maturity mismatch between the time-to-maturities of their assets and liabilities to react most restrictively. Considering these banks in the sub-sample reveals that they are somewhat smaller in terms of loan volume than the average bank in the sample.

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21 Using the same definition as in the dummy approach.

22 See e.g. Frühwirth-Schnatter and Kaufmann (2006) for Austria.

23 If we use a pooled regression, we obtain estimated coefficients that are in between the two other coefficients.

Without wanting to stretch our example too far, we present a back-of-the-envelope calculation that illustrates the relevance of the bank capital channel. In 2004, the overall loan volume to companies and private clients was about € 2.2 trillion in Germany. We assume for simplicity that, of the lower 50 percent capitalized banks, half the banks with the smallest interbank liquidity and greatest exposure to maturity transformation costs represents roughly about a quarter of the lending volume. Furthermore, we take the results from the most conservative estimation, saying that those banks reduce their lending by an additional 0.1 percentage point in the long run (compared to their average peers) if the interest rate goes up by 1 percentage point. Our back-of-the-envelope calculation indicates that those banks would reduce their loan supply by € 600 million in the long run.

Even if banks' customers can replace loans from their "house bank" with other sources of finance, they may have to bear considerable switching costs. The numbers therefore suggest that the bank capital channel may have significant effects in Germany, especially if the loan supply exerts a multiplier effect on real economic activity. A more detailed analysis would go beyond the scope of this study and will be left for future research. To do so, it would be necessary to analyze the reaction of bank customers to such a pattern, i.e. the substitutability of loans.

5 Concluding Remarks

This paper provides evidence that the bank capital channel hypothesis is relevant to Germany. The outlined theoretical framework adds an asset buffer to the existing theory and shows its relevance in the empirical regressions. Banks with lower asset and lower capital buffers that face maturity transformation costs react more restrictively to a monetary tightening than their average peers.

We find evidence in favor of a meaningful interaction of interbank liquidity, capital buffer and maturity transformation costs for the entire sample as well as for the sub-samples for savings banks and credit cooperatives. Interestingly, the second asset buffer measure, which additionally contains securities and shares, performs far worse than interbank liquidity. There is only some weak evidence for its relevance in the savings bank sector. The underlying reason for this pattern may be an interesting question for future banking research.

The results indicate the existence of the bank capital channel. Although the bank lending channel may exist in parallel, we are confident that our findings are driven by the bank capital channel. However, as no framework to discriminate the two channels exists, we cannot test the two channels against one another more rigorously. Hence, future research on developing such an analytical framework would be highly desirable.

In terms of affected lending volume, the results seem economically significant and indicate that the bank capital channel may be an important source of monetary policy transmission for Germany. However, the question as to the size of the effects can only be answered with more evidence about the substitutability of bank loans that are affected by potential reductions in the loan supply after a monetary tightening. Furthermore, calibrated dynamic stochastic equilibrium models of the Bernanke et al. (1999) type, which could try to incorporate the bank capital channel explicitly, may deliver further insights into potential effects. Both issues are surely a major challenge for future research.

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Appendix A: A Simple Theoretical Model

The balance sheet identity of a representative bank looks as follows:

$$CL + OI = CD + IBD + K\ .$$

The assets side of the bank consists of customer loans (*CL*) and other investments (*OI*), which are for simplicity interbank loans, securities, and cash. The liabilities can be separated into customer deposits (*CD*), interbank deposits (*IBD*), and bank capital (K). The overall bank capital consists of required capital (R) and excess capital (X): *K=X+R*.

We assume that capital in period *t* (K) is predetermined by the capital stock one period before plus retained profits ($K_t = K_{t-1} + \pi_{t-1}$).[24] Banks have to take the capital requirement into account when maximizing the profits.[25]

The customer loan demand is determined by the following function:

$$CL^d = -a_1 i_L + f(macro)\ .$$

It depends on loans' interest rate and a set of different macro variables.[26] Banks act as monopolistic competitors[27] and choose a profit maximizing loan volume on the demand schedule.

To incorporate the *bank lending channel* in our model (see Section 2), we assume that the customer deposit[28] demand is negatively related to the opportunity cost (risk free interest rate):

$$CD = -di_m\ .$$

where d>0. If the central bank tightens monetary policy, banks will acquire fewer deposits.

---

24 For simplicity, we assume that issuance of new capital is not possible and that no dividends are paid. This assumption may seem extremely restrictive, but we consider it as quite realistic for the savings banks and credit cooperatives sector where banks do not have access to equity markets. Furthermore, it is widely used in the literature (see e.g. Rochet, 1992).

25 The restriction writes $K \geq kL = k(CL + v * OI)$, where k is the capital requirement ratio. The formula is consistent with the Basel I capital requirement, which obliges banks to hold 8% capital for customer bank loans. Other investments (except for cash) are also subject to capital requirements, albeit to a somewhat smaller extent (v<1), since e.g. loans to other domestic banks only have a risk weight of 20%.

26 We do not specify theses variables in advance, but determine them empirically by comparing the estimation with time dummies to a specification with a set of macro variables.

27 Alternatively to market power convex screening costs would lead to a downward sloping demand schedule.

28 The interest rate of deposits is normalized to zero.

Furthermore, we assume that other investments stand in a fixed relation to customer deposits, which banks hold to compensate for unexpected deposit outflows:

$$OI = sCD.$$

Asymmetric costs of finance are the second assumption that is necessary for the bank lending channel to work. Banks, which are member of a liquidity network, usually re-finance at the respective head institution (which is at least partly owned by its members).[29] We assume that re-financing costs depend on the financial situation (FS_H) of the respective head institution.

$$i_{IB} = i_m\left(\mu_H - c_H FS_H\right),$$

FS_H is an indicator for the financial strength of the respective head institution, μ_H and c_H are positive constants. We consider the capital buffer of the head institution to be a good proxy for the financial strength. The liquidity network's head institution either had an AAA or at least a very good investment grade rating[30] during our observation period. Thus, there only appears to be one important plausible case to us that could put the head institutions under financial distress. If their own capital buffer is relatively low, they could be forced to act more restrictively after a monetary tightening and to restrict the liquidity provision to their network members.

If the head institution has a sufficiently high capital buffer, we would expect $\left(\mu_H - c_1 FS_H\right) = (1+m)$, i.e. all network members have the same cost of re-financing, which is equal to the risk-free market level plus a markup (m).

In order to incorporate the *bank capital channel*, we assume that banks face maturity transformation costs

$$MTC = \rho_{t-1}\Delta i_m IBA_{t-1},$$

depending on the time-to-maturity mismatch of assets and liabilities (captured by ρ_{t-1} which is predetermined in period t-1, see Appendix B for its empirical definition) and the amount of interest bearing asset whose time-to-maturity goes beyond period t-1 (IBA_{t-1}), which is also predetermined in period t-1.

Banks maximize the following objective function[31]:

---

[29] See Ehrmann and Worms (2004) for empirical evidence. Alternatively, they could re-finance by issuing bonds. But this source of finance is very small for local savings banks (4% of liabilities in December 2004) and credit cooperatives (6% of liabilities) in Germany.

[30] The head institutions of the credit cooperatives sector have a similar rating as Germany's biggest commercial banks.

[31] Letters without time subscript refer to period *t*.

$$Max\pi = i_L CL - zCL + i_m OI - i_{IB}(FS_H)IBD - \rho_{t-1}\Delta i_m IBA_{t-1} - EC(ab_{t-1}, x_{t-1}, MTC, CL),$$

where z is an indicator for the risk profile of the bank (e.g., the average proportion of non-performing customer loans) which reduces profits.

In this setting the bank maximizes its profit and attaches a certain expected cost (EC) to an expected violation of the capital requirements. A violation of the minimum capital requirement among other things would lead to an enormous loss of reputation, probably a replacement of the banks' management, and a tight control by the supervisory authority.[32]

First, EC is a function of the capital buffer to total assets in the previous period (x_{t-1})[33], which serves a buffer function on the liabilities side. The bigger the capital buffer accumulated in the previous period, the lower is the probability that the bank will hit the minimum capital requirements ($\partial EC / \partial x_{t-1}$).

Second, *EC* depends on the asset buffer in the previous period (ab_{t-1}), which we define as short term risk-weighted assets (predetermined in period *t-1*). In the empirical estimation, we use two different measures thereof. The first one consists of short-term interbank loans, which will soon be liquidity and thus relieve the capital constraint in the near future. The bigger this position, the lower is the expected cost of falling below the capital requirement ($\partial EC / \partial ab_{t-1} < 0$). The second measure additionally contains securities and shares, which can easily be liquidized. However, securities and shares have the disadvantage that they are subject to interest rate risk. If the interest rate increases, their value potentially has to be revised downwards.

Third, the expected loss of falling below the minimum capital requirement depends on the exposure to maturity transformation costs, caused by interest rate changes triggered by the central bank. The exposure to maturity transformation costs is determined by the balance sheet structure (ρ_{t-1}), depending on the business strategy in previous periods. The interest rate is exogenous to the bank. If the interest rate increases, there are maturity transformation costs, since it is one of the basic functions of a bank to accept short-run deposits and to provide loans with a longer time-to-maturity (see e.g. Freixas and Rochet, 2004). As a consequence, the equity value of the bank decreases or grows at least slower ($\partial EC / \partial MTC > 0$).

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[32] Even though one may expect that other members of the respective liquidity network inject equity into a troubled bank (e.g. by a merger), the bank's management has a strong incentive to prevent such an event.

[33] Small letters in the model denote for relative numbers, compared to capital letters, which denote absolute numbers.

The only variable that can be influenced by the bank in the current period is the *new* customer loan supply which determines the capital requirement. If the bank issues fewer loans, its capital requirements and thus the expected cost of falling below the capital requirement will be smaller ($\partial EC / \partial CL > 0$).
Using the above system, we obtain the following optimal loan supply:

$$CL = \frac{1}{2} f(macro) - \frac{a_1}{2} z - \frac{a_1}{2} (\mu_1 - c_1 X_{HI})(1-k) i_m - \frac{a_1}{2} \frac{\partial EC}{\partial CL} (ab_{t-1}, x_{t-1}, MTC, CL) \cdot$$

For simplicity, we assume the following functional form:

$$EC = f(ab_{t-1}, x_{t-1}) * MTC * CL .$$

We specify further that the asset and capital buffer interact as follows:

$$f(ab_{t-1}, x_{t-1}) = (\mu_1 - c_1 ab_{t-1})(\mu_2 - c_2 x_{t-1})$$
$$= \mu_1 \mu_2 - \mu_2 c_1 ab_{t-1} - \mu_1 c_2 x_{t-1} + c_1 c_2 ab_{t-1} * x_{t-1}$$

where μ_1, μ_2, c_1, and c_1 are positive constants, which means that bigger asset and capital buffers in previous periods reduce the expected costs of falling below the capital requirement.

If we use this specific form, we obtain the following optimal loan supply:

$$CL = \frac{1}{2} f(macro) - \frac{a_1}{2} z - \frac{a_1}{2} (\mu_1 - c_1 X_{HI})(1-k) i_m + \frac{a_1}{2} \mu_2 c_1 ab_{t-1} MTC$$
$$+ \frac{a_1}{2} \mu_1 c_2 x_{t-1} MTC - \frac{a_1}{2} c_1 c_2 ab_{t-1} * x_{t-1} MTC + K$$

where K assembles all constants that are not relevant for the estimation.
The simple theoretical model tells us that the loan supply depends in a negative way from the risk profile (z) of the banks and the market interest rate (i_m). Furthermore, we expect the coefficient for the interaction term of asset (capital) buffer and maturity transformation costs to reveal a positive sign. The model predicts that the coefficient for the interaction term of asset buffer, capital buffer and maturity transformation costs shows a negative sign.

We use the above reduced form for our empirical estimation to analyze if banks react in the predicted way. As we do not know the right set of macro-variables in advance and as there is always the danger of not capturing the time effects properly and thus obtaining seriously biased coefficients for the micro-variables, we replace all macro-variables in the baseline regression with a set of time dummies. This comes at the price that we do not know the reaction of the average bank to interest rate changes and other macro variables. To overcome this problem, we experiment later which set of macro variables leads to similar estimated coefficients for the micro-variables.

To capture the dynamics fully, we add lags to explanatory variables. Furthermore, we add the asset and capital buffer as level terms to keep our estimated specification as general as possible and to prevent an omitted variables bias.

Thus, we estimate the following equation:

$$\begin{aligned}
\Delta \ln Loans_{it} &= \sum_{j=1}^{4} \alpha_j \Delta \ln Loans_{it-j} + \beta Capital\ Buffer_{it-1} + \gamma Asset\ Buffer_{it-1} + \delta Risk_{it-1} + \\
&+ \sum_{j=1}^{4} \lambda_j Rho_{it-j} \Delta MP_{t-j} + \sum_{j=1}^{4} \varphi_j Capital\ Buffer_{it-j} Rho_{it-j} \Delta MP_{t-j} + \\
&+ \sum_{j=1}^{4} \omega_j Asset\ Buffer_{it-j} Rho_{it-j} \Delta MP_{t-j} + \sum_{j=1}^{4} \upsilon_j Capital\ Buffer_{it-j} Asset\ Buffer_{it-j} Rho_{it-j} \Delta MP_{t-j} + \\
&+ \sum_{j=1}^{4} \vartheta_j Capital\ Buffer_{head\ of\ i,t-j} Rho_{head\ of\ i,t-j} \Delta MP_{t-j} + \sum \tau_t TimeDummies + u_{it}
\end{aligned}$$

The underlying idea is that banks react to maturity transformation costs (in dependence of the size of the two buffers) by adjusting new loans. Since the average maturity of loans in Germany is longer than one year, the quarterly flow can be approximated by first differences.

Furthermore, if the head institutions’ capital buffer is sufficiently low, this may worsen the members’ re-financing conditions. In the baseline regression, which we run for the whole banking system, we omit this option, since we can only match head institutions and member banks for the savings bank sector, but not for credit cooperatives.

Appendix B
The Dataset

The Raw Dataset
Our raw dataset consists of bank-level confidential supervisory data on German universal banks (commercial banks, savings banks with their central giro institutions, and credit cooperatives with their central giro institutions) for the 1999:03 to 2004:12 period.[34] While the balance-sheet data is available on a monthly basis, the data on loan-loss provisions and time-to-maturity of interest-bearing assets is only available on an annual basis.

In line with the literature (e.g. Worms, 2003), we use a quarterly frequency in order to capture the dynamic structure properly. For the balance-sheet data, we use every third observation in time, while for the data on loan-loss provisions, we distribute the provisions over the four quarters of a year, though not uniformly: we interpolate between every two subsequent years in order to avoid jump discontinuities at the end of each year.[35]

The Variables
The variable definitions are given in Table A1. Our two variables of interest, *Capital Buffer* and *Asset Buffer*, are described in more detail in the following.

The *Capital Buffer* is defined as follows:

$$Capital\ Buffer_{it} = \frac{EC_{it}}{A_{it}} - \frac{\sum_{i(BG)} EC_{it}(BG)/A_{it}(BG)}{N_t(BG)},$$

where excess capital (EC_{it}) is actual regulatory capital minus minimum regulatory capital, A is total assets, and N is the number of banks. Hence, our capital buffer variable is scaled by total assets and demeaned by the period's mean of excess capital.[36] We do not use the overall period's mean, but the mean

34 In contrast to *subsidiaries* of foreign banks, we do not include *branches* of foreign banks, as their business activities in Germany are more likely to be driven by their headquarters than by euro-zone monetary policy or total economic activity in Germany. Further, their loan growth series often start from a very low level, therefore show very high growth rates and are extremely volatile. As a consequence, the inclusion of branches of foreign banks would bias the loan growth rates strongly upwards.

35 The variable is divided by four before interpolating. To prevent an endogeneity bias, we start instrumenting loan-loss provisions with the fourth lag.

36 We demean the data by the period's mean in order to remove the time trend that is existent in the data. For descriptive statistics, see Deutsche Bundesbank (2005).

of the respective banking pillar[37] (BG), since the pillars differ greatly with regard to capitalization due to the pillars' institutional rules (see e.g. Koetter et al., 2004).

Asset Buffer is defined as follows

$$Asset\ Buffer_{it} = \frac{B_{it}}{A_{it}} - \sum_{j}^{T} \frac{\sum_{i(BG)} B_{it}(BG)/A_{it}(BG)}{N_t(BG)} / T$$

where B_{it} are assets (other than loans) that have a non-zero regulatory risk weight and a short time-to-maturity or that can be easily liquidized, A is total assets, N is the number of banks, and T is the number of observations over time. Hence again, we scale our measure by total assets and normalize it by the mean of the respective banking group. In this case, however, we do not use the period's mean but the overall mean since there is no time trend visible in the data.

We use two different subcategories of assets to construct B and, hence, *Asset Buffer*. First, we use short-term interbank market liquidity, which consists of interbank market assets with a time-to-maturity of less than one year.[38] These positions are subject to capital requirements, although only weighted with 20%, and will expire within one year. Thus, they would reduce the required capital and can serve as a buffer. This is our baseline measure, as it accounts for the existing liquidity networks in Germany. As a robustness check, we use an alternative measure that also includes shares and bonds. These two additional positions are also subject to capital requirements and can easily be liquidized. The major shortcoming is that they are subject to interest rate risk. Liquidizing them after an increase in the market interest rate may result in a loss.

For the calculation of market volatility, we use a procedure similar to that of Baum et al. (2004a). We extract the intra-quarterly volatility from daily data on interbank market interest rates, government bond yields, and interest rate spreads.

The daily contribution to quarterly volatility is defined as:

$$\varsigma_t^{\,d} = \left(100 * \frac{\Delta i_t^{\,D}}{\sqrt{\Delta T}}\right)^2,$$

where Δi_t^{D} are daily interest rate changes.[39] They are normalized by the number of days between two observations (ΔT). If there is, for instance, a weekend between two trading days, ϕ_t rises to three.

The intra-quarterly volatility is defined as

[37] We distinguish three pillars: savings banks, credit cooperatives and commercial banks.

[38] This is the same measure used by Worms (2003) in a somewhat different context.

[39] We obtained the following daily data from Datastream: the three-month money market interest rate and the one-year, two-year, five-year and ten-year government bond yields. In addition, we calculated several term spreads thereof.

$$\sigma_t(i_t) = \sqrt{\sum_{t=1}^{T} \varsigma_l^{\,d}}$$

The different measures interest rates, yields and spreads we used showed similar results. For simplicity, we only show the results for the three-month EURIBOR volatility in the main part.

Risk is defined as new loan loss provisions and loan write-offs divided by total assets. By contrast, the empirical literature normally uses non-performing loans as a risk proxy. However, data on non-performing loans is not available for German banks. As new loan-loss provisions and loan write-offs are only available on a yearly basis, we interpolate the data linearly to obtain quarterly data, as we do with our measure of *Rho*.

Rho is a proxy for the cost a bank faces after a monetary tightening by the central bank due to the maturity transformation and is calculated as follows:

$$Rho_i = \frac{\sum_j (\chi_j \cdot A_j - \zeta_j \cdot P_j)}{\left(\sum_j A_j + \sum_j P_j\right)/2}$$

A_j and P_j are assets and liabilities classes with different time-to-maturity. The Deutsche Bundesbank's prudential database contains six maturity classes.[40] The sensitivities (χ_j and ζ_j) are obtained directly from the supervisory regulations.[41] We divided by the average size of interest-bearing assets and liabilities to normalize for the size of a bank.

In order to determine the existence of a bank capital channel, it is necessary to consider the change in a bank's profits due to a change in the interest rate. We therefore need to take into account all interest-bearing assets and liabilities rather than those merely existing in the trading portfolio. The extent to which a bank is exposed to interest rate changes is dependent on the degree of maturity mismatch held by the bank.

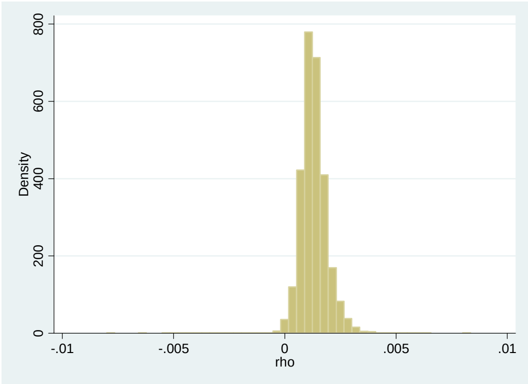
Since the regulatory data (maturity classes and risk) is only available on a yearly basis, we interpolated it linearly to obtain quarterly data.

A positive *Rho* indicates maturity transformation costs. As can be seen in the chart below, these costs are faced by most German banks.

---

40 Interest-bearing assets and liabilities with time-to-maturity shorter than one year, one to two years, two to three years, three to four years, four to five years, and above five years.

41 The Amendment to the Basel Accord to Incorporate Market Risks, Basle Committee, January 1996. Since these maturity classes are more detailed, we had to use averages for the available maturity classes.



Variable Definitions

Variable	Definition
Loan Growth	Quarterly growth in domestic loans to non-financial firms and to private customers
Risk	Yearly new loan-loss provisions and loan write-offs equally spread over the four quarters of a year divided by total loans
Capital Buffer	Regulatory capital minus risk-weighted assets divided by total assets; demeaned by group-year means.
Asset Buffer	Interbank claims that are due on demand or within one year divided by total assets; demeaned by group means.
Rho	Proxy for the term structure mismatch between assets and liabilities. The bigger a positive *Rho*, the bigger a bank's maturity costs after a monetary tightening.
ΔMP	Absolute change in the three-month EURIBOR (=monetary policy indicator)
GDP Growth	Quarterly nominal GDP growth
Volatility	Intra-quarterly volatility of the three-month EURIBOR. The numbers are derived from daily data.
High	Dummy variable that is unity if the bank's average capitalization is above the median excess capitalization in the sample and zero otherwise.
Low	Dummy variable that is unity if the bank's average capitalization is below the median excess capitalization in the sample and zero otherwise.

Notes: The bank-specific variables come from a confidential supervisory dataset kindly provided by the Deutsche Bundesbank, while the macroeconomic variables were obtained from the International Financial Statistics from the International Monetary Fund. The numbers on daily Euribor fluctuations were obtained from Datastream.

Treatment of Mergers

During the observation period, the banking system underwent a strong consolidation wave. For our analysis, it is important to identify these mergers, as otherwise there would be unexplained jumps in the loan growth series, which could lead to seriously biased results.

There are several alternative ways of treating mergers. First, banks involved in mergers can be completely discarded from the sample. However, as there were several hundred mergers during the observation period, especially between local savings banks and between cooperative banks, this would lead to a significant loss of information. The second option is to merge banks backwards. This procedure hinges on two assumptions. First, banks are assumed to behave as one entity, even pre-merger. And second, their behavior does supposedly not change post-merger. As these assumptions seem to be pretty severe to us, we choose the third option, i.e. to create a new notional institute after two banks merge. This causes the number of banks to increase, because there is one additional bank for each merger (the merging banks stay in the sample until the time of the merger, and the newly created bank after the merger). The drawback of this procedure is that we lose information, since all banks with six or less observations drop out of the regressions.[42] If we delete all banks with less than seven observations, the sample shrinks by between 0.5 and 15% in terms of the banking sector's total loans.[43]

Treatment of Outliers

In a panel framework it is crucial to identify outliers, as all banks — independently of their size — are weighted in the same way. If the sample is not cleaned, there is the danger of results being driven by extreme outliers. Deleting single outliers from the dataset would be extremely arbitrary. We therefore elect to drop the whole time series for a bank if some observations for this bank exceed a certain threshold. As thresholds we rely on percentiles, which we set according to visual inspection of the histogram for the respective variable. If we run robustness checks for different banking groups (not shown, but sometimes referred to in this paper), we apply this outlier identification procedure to the different banking groups separately. As this outlier identification procedure is

42 Differentiation of the dependent variable leads to a loss of one time period. Furthermore, four lags of the dependent variable are used as regressors. In addition, at least one more lag is needed for the instrumentation.

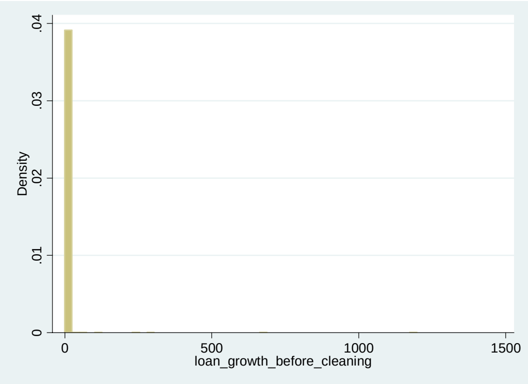
43 The loss of information is not entirely due to the treatment of mergers, as there have also been banks with less than seven periods. The attrition is of course the biggest at the borders of the sample and the smallest in the middle of the sample. When we cut a bank e.g. in the first quarter of 2000 into two parts, the first five quarters drop out of the sample (at least seven time-series observations are needed to be included into the regression), whereas the later part remains.

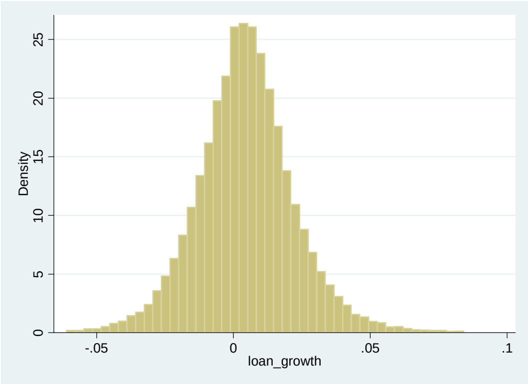
also somewhat arbitrary, we run robustness checks to see if the results depend on the chosen thresholds. However, they deliver the same qualitative results.

We use the following threshold for the standard specification, which we run for savings banks and credit cooperatives. For the dependent variable *Loan Growth*, we use the 1st and 99th percentile. For *Asset Buffer*, we use the 99th percentile only, as the variable is non-negative by construction. For *Capital Buffer*, we drop banks with negative observations: these banks may undergo transitional adjustments in accordance with the supervisory authority. Alternatively, they may be distressed and therefore under supervisory control. In this case, they could not take deliberate investment and funding decisions. However, we lack the data to discriminate between these two cases and, thus, drop the negative observations. In addition, we use the 99th percentile. As a result of this cleaning procedure, our remaining dataset covers about two thirds of the banking sector in terms of the lending volume.[44]

If we run regressions for the entire sample, we widen the cut-off values to the 2nd and 98th percentile for loan growth and to the 98th centile for the other variables. We effectively obtain a wider span of values, since they are much more dispersed for commercial banks.[45]

The following two graphs (the left graph shows loan growth for the entire sample before cleaning, the right one after cleaning) exemplarily show the necessity of a data cleaning procedure, illustrating that the uncleaned dataset would deliver seriously biased results.





44 When referring to results for the savings banks sector, we use only three lags of the explanatory variables, since this was sufficient to capture the dynamics.

45 We do not run any outlier procedure for *Rho* since the visual inspection revealed much fewer outliers. A robustness check showed that omitting the 1% and 99% centiles of *Rho* leads to similar estimation results.

Appendix C
Descriptive Statistics

Table A1: Descriptive Statistics[46]

	Banks with Low Capital Buffer		Banks with High Capital Buffer		Wilcoxon Test
	Mean	Std. Dev.	Mean	Std. Dev.	
Loans in Bn Euro	0.98	4.80	0.39	3.48	65.628***
Loan Growth	0.0054	0.0175	0.0037	0.0182	11.344***
Capital Buffer	0.0148	0.0055	0.0320	0.0116	-164.428***
Asset Buffer I	0.0598	0.0474	0.0732	0.0523	-30.135***
Asset Buffer II	0.2653	0.0906	0.3041	0.1009	-42.717***
Risk	0.0017	0.0012	0.0013	0.0009	38.708***
Rho	0.0013	0.0007	0.0013	0.0005	-15.470***

Notes: H_0 of the Wilcoxon rank-sum test: Samples are from an identical population versus two-sided alternatives. *** indicates statistical significance at the 1 percent level in a two-tailed *t*-test. Banks are classified as having a low capital buffer if they are on average among the lowest capitalized 50 percent of savings banks. For better comparability we deducted the sample's mean from all variables (except for loans and loan growth).

46 To prevent a loss of information, asset and capital buffers are given here without prior demeaning.

Table A2: Correlation Matrix

	Loan Growth	*Capital Buffer*	*Asset Buffer I*	*Asset Buffer II*	*Risk*	*Rho*	*ΔMP*	*GDP Growth*
Loan Growth	1.0000							
Capital Buffer	-0.0751*	1.0000						
	(0.0000)							
Asset Buffer I	-0.1155*	0.1453*	1.0000					
	(0.0000)	(0.0000)						
Asset Buffer II	-0.0505*	0.2228*	0.2758*	1.0000				
	(0.0486)	(0.0000)	(0.0000)					
Risk	0.1893*	-0.1661*	-0.0750*	-0.2360*	1.0000			
	(0.0000)	(0.0000)	(0.0000)	(0.0000)				
Rho	0.0561*	0.0897*	-0.1470*	0.1959*	-0.0610*	1.0000		
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)			
ΔMP	0.1027*	-0.0081	-0.0711*	-0.0195*	-0.0304*	0.0016	1.0000	
	(0.0000)	(0.0840)	(0.0000)	(0.0000)	(0.0000)	(0.7547)		
GDP Growth	0.0857*	-0.0800*	0.0110	0.0322*	-0.0502*	-0.0458*	0.5269*	1.0000
	(0.0000)	(0.0000)	(0.0196)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	
Volatility	0.1698*	-0.1168*	-0.0070	0.0084	-0.0656*	-0.0780*	0.0076	0.2166*
	(0.0000)	(0.0000)	(0.1373)	(0.0729)	(0.0000)	(0.0000)	(0.1035)	(0.0000)

Notes: * denotes significance at the 1 percent level. P-values are given in brackets below the correlation coefficient.

Appendix D

Robustness Check: Fixed Effects Regression Results

Table A3: Long-Term Coefficients for Estimating Eq. (1)—Fixed Effects

Dependent Variable: *Loan Growth*	(1) Baseline Without Macro Variables	(2) Baseline With Macro Variables
Risk	-5.01***	-5.03***
	(-20.01)	(-20.03)
Capital Buffer	0.27***	0.25***
	(9.02)	(8.29)
Interbank Liquidity (IL)	0.01*	-0.00
	(1.94)	(-0.26)
*Capital Buffer*Rho*ΔMP*	-0.13	-0.11
	(-0.40)	(-0.33)
*IL * Rho * ΔMP*	0.10	0.08
	(1.15)	(0.92)
*Capital Buffer * IL * Rho * ΔMP*	-0.23***	-0.23***
	(-2.86)	(-2.84)
*Rho * ΔMP*	-0.67	-1.09
	(-0.87)	(-1.42)
ΔMP		-0.19
		(-1.41)
GDP Growth		1.12***
		(13.88)
Time Dummies	Yes	No
# Obs. (Banks)	26676 (2273)	26676 (2273)

Notes: The table gives the long-term coefficients based on robust fixed effects estimations of Eq. (1). The dependent variable is *Loan Growth*, measured as the quarterly growth rate of domestic loans to non-financial firms and to private customers. *Risk* is defined as new loan-loss provisions plus loan write-offs divided by total loans. *Capital Buffer* is defined as regulatory capital minus risk-weighted assets divided by total assets. *Asset Buffer* is defined as short-term interbank claims divided by total assets. *Rho* is a proxy for the maturity transformation cost a bank faces after a one-percentage-point increase in the monetary policy indicator. *ΔMP* is defined as the absolute change in the three-month EURIBOR (=monetary policy indicator). *GDP Growth* is defined as quarterly growth rate of real GDP. To improve the readability of the table, the estimated coefficients for *Rho* ΔMP* are rescaled by the factor 10^{-2}, *Capital Buffer * Rho* ΔMP* and *Interbank Liquidity * Rho * ΔMP* by 10^{-4} and *Capital Buffer * Interbank Liquidity * Rho* ΔMP* by 10^{-6}. t-statistics are given in brackets. ***, **, and * indicate statistical significance at the 1, 5, and 10 percent levels, respectively, in a two-tailed *t*-test.

Table A4: Long-Term Coefficients for Estimating Eq. (1)—Fixed Effects

Dependent Variable: *Loan Growth*	(1) Dummies Without Macro Variables	(2) Dummies With Macro Variables	(3) Dummies With Macro Variables (incl. Volatility)
Risk	-4.94***	-4.96***	-4.86***
	(-19.90)	(-19.92)	(-19.46)
*Interbank Liquidity (IL)*Low*	0.00	-0.01	-0.01
	(0.06)	(-1.37)	(-0.75)
*Interbank Liquidity*High*	0.01*	0.00	0.01
	(1.79)	(0.10)	(0.65)
*IL*Volatility*Low*			0.04
			(0.72)
*IL*Volatility*High*			0.01
			(0.27)
*IL*Rho*ΔMP*Low*	0.26**	0.23*	0.25**
	(2.20)	(1.94)	(2.08)
*IL*Rho*ΔMP*High*	-0.17	-0.17	-0.12
	(-1.41)	(-1.44)	-0.92
*Rho*ΔMP*Low*	-0.15	-0.54	-0.54
	(-0.20)	(-0.67)	(-0.67)
*Rho*ΔMP*High*	-0.97	-1.43	-1.52
	(-1.15)	(-1.69)	(-1.78)
ΔMP		-0.20	-0.86
		(-1.50)	(-4.58)
GDP Growth		1.10***	1.93***
		(13.77)	(13.30)
Volatility			-1.27***
			(-4.64)
Time Dummies	Yes	No	No
# Obs. (Banks)	26681 (2273)	26681 (2273)	26681 (2273)
Adj. R-squared	0.1569	0.1358	0.1420

Notes: The table gives the long-term coefficients based on robust fixed effects estimations of Eq. (2). Volatility is measured as intra-quarterly volatility of the three-month EURIBOR based on daily data. For the other variable definitions, see Table 1. For better readability, the estimated coefficients for *Rho*ΔMP* are rescaled by the factor 10^{-2}, *Capital Buffer*Rho* ΔMP* and *Interbank Liquidity*Rho*ΔMP* by 10^{-4}, *Capital Buffer*Interbank Liquidity*Rho*ΔMP* by 10^{-6}, Volatility by 10^{4}, and *Interbank Liquidity*Volatility* by 10^{2}. t-statistics are given in brackets. For savings banks, we use only three lags of the endogenous variables, since this is sufficient to capture the dynamics. ***, **, and * indicate statistical significance at the 1, 5, and 10 percent levels, respectively, in a two-tailed *t*-test.