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. When 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

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[1] For a quite broad but somewhat outdated overview, see Symposium on the Monetary Transmission Mechanism, Mishkin (1995).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).

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 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.

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

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

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

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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).

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 cooperatives and savings banks, the amount of customer deposits is bigger than the amount of overall loans. From 1999 to 2004, this

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

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 Merkl and Stolz , 2006). Finally, all German banks are subject to minimum capital requirements.

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[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.

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 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

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[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.

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). 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, $Rho*\Delta MP$ 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 Merkl and Stolz (2006).

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

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

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. 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. For the formalization of the intuition in a model see Merkl and Stolz (2006).

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.

We use short-term interbank ("interbank liquidity") assets with a maturity up to one year as our measure for the asset buffer. [Hier sollten wir noch schreiben, warum wir

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[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.

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.

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.[14]

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]

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

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[14] 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.

[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).

We expect banks with a lower capital buffer to react more restrictively if they face maturity transformation costs ($\varphi > 0$) caused by a monetary tightening. Similarly, we expect the same for banks with a lower asset buffer ($\omega > 0$). 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 ($\upsilon < 0$). 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 ($\upsilon < 0$), 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.

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).[16]

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 Merkl and Stolz (2006).

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 Reaction of Monetary Policy

Baseline Regression

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[16] In Merkl and Stolz (2006) the estimation results from a fixed effects specification are shown and deliver the same qualitative outcome.

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).

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

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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.

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 A 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.

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.

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.

4.2 Maturity Transformation Costs and Firms' Profits

In this subsection we analyze whether maturity transformation costs, as defined by our proxy, are able to influence the interest income of banks significantly. This is an important precondition for the bank capital channel to be active. 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

Dependent Variable: *Interest Income$_t$*	(1) Robust Standard Errors	(2) AR(1) Standard Errors	(3) 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.

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.[19] In terms of loan volume (assets), they are, on average, about 2.5 (3) times bigger than their well-capitalized peers (see Appendix B). Thus, in contrast to many studies for the bank

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[19]   Using the same definition as in the dummy approach.

lending channel,[20] 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.[21]

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.

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

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[20]   See e.g. Frühwirth-Schnatter and Kaufmann (2006) for Austria.

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

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. Conclusion

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 asset buffer, capital buffer and maturity transformation costs for the entire sample as well as for the sub-samples for savings banks and credit cooperatives.

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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