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# The transmission of bank capital requirements and monetary policy to bank lending in Germany

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## Abstract

We investigate the transmission of changes in bank capital requirements and monetary policy, and their interaction, on German banks' corporate loan growth and lending rates. Our results show that increases in capital requirements are associated with an immediate decrease in total domestic and cross-border bank lending. Changes in the euro area's monetary policy stance are positively related to corporate loan interest rates in general. Regarding the interacting effect of national bank capital requirements and euro area monetary policy, we observe that the transmission of accommodative euro area monetary policy to corporate lending rates can be attenuated by contemporaneous increases in bank capital requirements. Moreover, more strongly capitalized banks increase their loan growth in response to accommodative monetary policy whereas, for weaker banks, increasing capital requirements implies a decrease in their corporate loan growth. Our results confirm a tradeoff between higher capital requirements and accommodating monetary policy originating from banks' capital constraints.

## JEL CLASSIFICATION

E52; F30; G28

[Correction added on 12 January 2021, after first online publication: Ursula Vogel was designated as co-corresponding author.]

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## 1 | INTRODUCTION

After the global financial crisis, banking regulation in Europe underwent a comprehensive overhaul, in particular with respect to bank capital. Microprudential capital requirements were tightened and complemented with several macroprudential measures to provide regulators with (further) tools which could address systemic risks. At the same time monetary policy—in the euro area as well as in other major economies—was characterized by an accommodative monetary policy stance. As the banking system is a major transmission channel for monetary policy and capital regulation alike, the implications of the two policies with respect to bank lending and interest rates<sup>1</sup> deserve closer attention. This paper aims to contribute to the understanding of the transmission of bank capital requirements as well as international monetary policy, and the interaction between the two policies, on euro area bank lending and the corresponding interest rates. Consequently, it sheds light on domestic as well as international implications of national and international policy interactions, focusing on immediate effects.

Both policies have been investigated in the empirical literature, though often only separately. The evidence on the immediate effects of changes in bank capital requirements is mixed. Aiyar, Calomiris, and Wieladek (2014) observe a decrease in lending in response to higher capital requirements, while a survey by the Basel Committee on Banking Supervision (1999) of more than 130 research papers on the effects of Basel I suggests that this is the case in economic troughs only. Other studies argue that the effects depend on the industry sector (Bridges et al., 2014), bank dependency (Gropp, Mosk, Ongena, & Wix, 2018), banks' rating approach (Behn, Haselmann, & Wachtel, 2016), or bank type (De Jonghe, Dewachter, & Ongena, 2020). Jiménez, Ongena, Peydro, and Saurina (2017) investigate dynamic provisioning of capital requirements and find that it helps smooth the credit cycle. Francis and Osborne (2012) and Imbierowicz, Kragh, and Rangvid (2018) show that banks tend to adjust the risk composition of their asset portfolio in response to an increase in capital requirements rather than the volume of loan portfolios. Further implications hinge on the time horizon analyzed. Some papers examining the long-term implications find transitory adverse implications (see e.g., Eickmeier, Kolb, & Prieto, 2018); in the long run, higher bank capital seems associated with higher loan volumes (see e.g., Buch & Prieto, 2014 for an analysis of the German banking system). As to the impact of monetary policy, the results in the literature suggest that its effects on bank lending depend on banks' risk.<sup>2</sup> While the central bank policy rate has an effect on banks' risk-taking and leverage, and therefore financial stability (for an overview, see e.g., Gambacorta, 2009), prudential capital requirements generally induce a change in banks' funding mix and accordingly their costs, and thereby affect their response to policy changes. Some more recent studies have also looked into the interaction between the two policies. Takáts and Temesváry (2019) find significant interactions between macroprudential policy in general and monetary policy associated with the currency of cross-border bank lending. Tighter macroprudential policy mitigates the lending impact of monetary policy, whereas an ease of macroprudential policy amplifies the lending impact of monetary policy. Some studies investigate the interaction between monetary policy and bank capital requirements. Aiyar, Calomiris, and Wieladek (2016) find in a study for the United Kingdom that a tightening of both capital requirements and monetary policy reduces bank lending. However, they find little evidence of an interaction between the two policy instruments. De Marco and Wieladek (2016) also study bank-specific capital requirements and monetary policy in the United Kingdom and the consequences for SMEs. They find that effects differ depending on the bank-firm relationship and firms' dependency on banks, as well as bank and firm characteristics. Empirical evidence presented by Budnik and Bochmann (2017) shows that the response of better capitalized banks' loan growth to changes in monetary policy is less severe. Relatedly, Gambacorta and Mistrulli (2004) and Maddaloni and Peydro (2013) illustrate that lending by poorly capitalized banks responds more strongly to changes in monetary policy rates. Eickmeier et al. (2018)

show for the United States that monetary policy cushions negative short-term effects of capital requirement tightenings. We are not aware of studies looking at the implications on lending rates.

In our paper, we examine the impact of changes in bank-specific capital requirements and the euro area monetary policy interest rate on the total of banks' domestic and cross-border lending to the non-financial corporate sector in the euro area and the interest rate charged for these loans. Our sample covers the period from 2008:Q1 to 2018:Q3 for a sample of banks in Germany. We analyze the effects of the euro area monetary policy stance accounting for the transmission of changes in bank capital requirements. To this aim, we follow the overall specification and modeling choices of the other papers included in this special issue, as summarized in Bussière et al. (2020). As a measure for the monetary policy stance, we use the cumulative changes of the interbank money market interest rate over the previous year. Bank capital requirements are calculated as the bank-specific capital requirement ratio (required regulatory capital/risk-weighted assets) multiplied with the average risk weight of the corporate loan portfolio (risk-weighted corporate loan exposure/unweighted corporate loan exposure, also called "risk-weighted asset (RWA) density"). The measure accordingly does not only account for regulatory changes of a bank's capital requirement but also for the sensitivity of banks with respect to these. It allows to differentiate banks' response to changes in regulatory capital requirements by their degree of "affectedness" and therefore includes more variation in the time dimension than mere regulatory changes.

As a first step, we investigate the effect of changes in capital requirements on euro area corporate lending as well as on the related lending rates using a simultaneous equations regression design. We find that higher capital requirements are, on average, associated with an immediate reduction in the total of domestic and cross-border lending. We do not observe an effect on lending rates. We then investigate whether the effect of changes in capital requirements on lending and lending rates depends on the level of a bank's capital. To do so, we calculate a bank's excess capital, that is, the difference between its regulatory capital requirement and its actual capital ratio. We observe that the decrease in lending in response to higher capital requirements derives from banks with lower levels of excess capital. A 1 percentage point increase in bank capital requirements implies a 1.5 percentage point lower loan growth for these banks. We acknowledge that dynamics might be different over longer time horizons as banks may target a bank- and time-specific optimal capital ratio (e.g., Gropp & Heider, 2010). Furthermore, we cannot rule out substitution effects. Banks might decrease their lending to the corporate sector but increase lending to other sectors with, for example, lower risk weights (e.g., Gropp et al., 2018; Imbierowicz et al., 2018).<sup>3</sup> Our finding complements the results of Buch and Prieto (2014) who also look at the German banking system. While they show that aggregate and long-term implications of higher bank capital for lending are positive, we add to this by exploring short-term effects and by pointing out that possible transitory adverse effects hinge on the excess capitalization of banks.

As a second step, we additionally analyze the effects of changes in the euro area monetary policy stance. We find that changes in the monetary policy stance, tightening as well as easing, are positively correlated with changes in euro area lending rates. However, the effect of monetary policy tightening on interest rates is relatively stronger than monetary policy easing.<sup>4</sup> We observe that a decrease (increase) in the monetary policy rate of 1 percentage point implies a decrease of 0.039% (increase of 0.181%) of the quarterly change in lending rates on the total of outstanding loans vis-à-vis corporates. Our results suggest that corporate loan growth increases in response to an accommodative monetary policy but only for banks with higher levels of capitalization. This is in line with the findings of Acharya et al. (2020) who show that banks' capital constraints might reduce the effectiveness of the bank-lending channel in periods of monetary policy easing.

In a third and last step, we explore the interaction effect of capital requirements and euro area monetary policy on bank corporate loan growth and interest rates in more detail. We hypothesize that prudential regulation and monetary policy are likely to interact in their effects as for both types of policy the banking sector is a major transmission channel. Accordingly, both types of policies might have an effect on bank refinancing costs, which, in turn, might affect lending rates and volumes. The transmission of one policy may be affected by changes to the other. Our results show that changes in the monetary policy stance are attenuated when capital requirements change in the opposite direction. This implies that an easing of monetary policy translates into a smaller decrease in bank lending rates if capital requirements are tightened at the same time. Correspondingly, lower bank capital requirements might cushion the effects of policy rate hikes. These analyses again confirm our previous results that higher capital requirements imply a decrease in the lending for weaker capitalized banks while loan growth of better capitalized banks increases when monetary policy is accommodative.

Our findings add to the still rather scarce empirical literature on the joint effects of capital regulation and monetary policy on bank lending, and show that bank regulation and monetary policy should not only be considered individually as they also have interacting effects, and that real effects—which appear domestically and cross-border—crucially hinge on bank capitalization. Yet, it is to be noted that our analysis contributes to an improved understanding of *immediate* implications of policy changes for different types of banks, which are shown to be different from positive *long-term* or more aggregate implications (see e.g., Buch & Prieto, 2014; Eickmeier et al., 2018). Our results are also important for policymakers as a thorough understanding of the transmission of different policies and their interactions is crucial for maintaining the stability of the domestic as well as other financial systems, and the resulting implications for the real economy. They might further be useful for ex-ante assessments of envisaged policy changes, in particular with respect to unintended externalities and the understanding of their transitory nature. Most importantly, our paper contributes to the scarce literature in which the intensity of prudential policy changes is mapped to outcome variables.<sup>5</sup> The intensity measurement is useful for informing policymaking as it allows for a clear tracking of policy changes to the outcome variables, for instance lending, and is preferable to the more widely used dummy-coding of policy changes.

The remainder of the paper is structured as follows. Section 2 provides a brief overview of bank capital regulation and monetary policy in Germany. Section 3 describes the data, and Section 4 presents the empirical setup and results. Section 5 concludes.

## 2 | CAPITAL REQUIREMENTS AND MONETARY POLICY

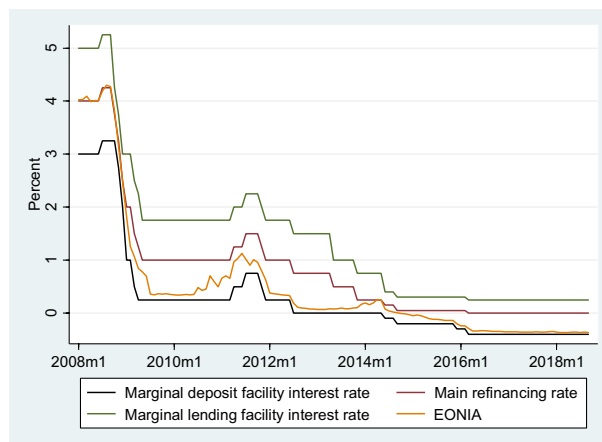
### 2.1 | Bank capital requirements in Germany

Our sample period starts in 2008:Q1 when Basel II was already in place. Basel II implied that banks are able to choose between the standardized approach (SA) and the internal ratings-based approach (IRBA) to determine the risk weight of a loan. In contrast to the SA, in which risk weights are assigned by predefined templates set by the regulator, the IRBA allows banks to determine risk weights based on their internal risk models, subject to approval by the regulator. In Germany, mainly large banks gradually shifted their loan portfolios from the SA to the IRBA upon the introduction of Basel II. This resulted in most cases in substantially lower risk weights for most of these banks' assets as well as in differences in risk weights across banks while regulatory requirements remained constant over time and equal across banks.

Since January 2014 most Basel III related provisions are applicable in the EU.<sup>6</sup> The requirements in Basel III imply a gradual tightening of capital regulations—both in terms of definitions and quantity of capital. From 2015 onwards, minimum capital requirements were complemented with additional macroprudential and microprudential capital buffers. As to the former, the Capital Conservation Buffer (CCoB) and buffers for systemically important financial institutions (SIFI buffers) were imposed. The CCoB is set to 2.5% for all banks and phased-in in four equal annual steps from 2016 on. As to SIFI buffers Deutsche Bank as a global systemically important bank had to fulfill a G-SIB buffer of 2% that was phased-in in four steps from 2016 on, while initially 16 “other systemically important institutions” received O-SII buffers between 0.5% and 2% which were phased-in in three steps from 2017 on. In addition, since 2015, bank-specific microprudential Pillar 2 capital requirements (based on the Supervisory Review and Evaluation Process—SREP) are determined annually by banking supervisors for those banks that are deemed to carry certain idiosyncratic risks. Apart from capital requirements, over our sample period from 2008:Q1 to 2018:Q3 no other (macro)prudential instruments—possibly affecting lending to non-financial corporates—have been implemented in Germany.<sup>7</sup>

## 2.2 | Euro area monetary policy and monetary policy stance

Monetary policy for Germany, as a member of the euro area, is conducted at the supranational level within the Eurosystem, which consists of the European Central Bank (ECB) and all euro area national central banks. Prior to October 2008, the ECB offered liquidity such that banks were able to exactly fulfill their reserve requirements. Liquidity was issued by the ECB in a competitive tender procedure and thereafter distributed in the markets such that each bank was able to fulfill its requirement. Since October 2008, in response to the crisis, the ECB sets a fixed main policy interest rate and provides liquidity according to banks’ demand (full allotment) provided banks have sufficient collateral.<sup>8</sup> It also conducts outright monetary transactions under the asset purchase program and extended the maturity of refinancing operations and the range of eligible assets that could be used as collateral for these operations. As a consequence, since October 2008 the ECB has been operating in an environment of surplus liquidity and the money market rate has approached the lower bound of the corridor (ECB



**FIGURE 1** Monetary policy rates. The figure shows key European Central Bank (ECB) policy interest rates together with the EONIA interest rate from 2008:Q1 to 2018:Q3 [Colour figure can be viewed at [wileyonlinelibrary.com](http://wileyonlinelibrary.com)]

marginal deposit facility interest rate). Figure 1 depicts the key policy interest rates and the money market rate from 2008:Q1 to 2018:Q3.

Prior to October 2008, the main refinancing rate and the overnight interbank money market rate (Euro Over Night Index Average, or EONIA) were close to each other. Since then, the EONIA interest rate has moved from being close to the main refinancing rate toward the lower bound of the interest rate corridor set by the ECB, that is, to the deposit facility interest rate. We, therefore, use the EONIA interest rate as our measure for the “true” euro area monetary policy rate. In our empirical analyses, we incorporate the cumulative change in the short-term money market rate over the current and the three previous quarters as a measure of the monetary policy stance. Alternative measures to explore the implications of monetary policy changes could be shadow rates (e.g., Krippner, 2013; Wu & Xia, 2016) or monetary policy surprises (Gürkaynak, Sack, & Swanson, 2005). However, we use the interbank interest rate (EONIA) for the monetary policy environment in our analyses as we focus on the direct interest rate transmission. Furthermore, our measure is directly related to banks’ funding conditions, which might translate most directly to their credit supply and reflects the euro area monetary policy environment better than other variables.<sup>9</sup>

### 3 | DATA AND MAIN VARIABLES

For our analyses, we use quarterly data from 2008:Q1 to 2018:Q3 from the Bundesbank's MFI interest rate and balance sheet statistics.<sup>10</sup> The MFI interest rate statistics are based on the interest rates charged by monetary financial institutions (MFIs) in Germany and the corresponding volumes of euro-denominated loans extended to private sector borrowers in the euro area. Our variables of interest are the q-o-q change in outstanding loans to the non-financial corporate sector<sup>11</sup> in the euro area, and the q-o-q change in the weighted average of the interest rates charged for these loans. The MFI interest rate statistics cover a representative sample of about 220 banks in the German banking system. These reflect about 70% of the entire German banking market in terms of total assets. Figure 2 shows the changes in corporate loan growth and interest rates and their distribution from 2008:Q1 to 2018:Q3. Both variables include a sufficient degree of variation both within and across time. The median values show that lending to corporates grows in most time periods while corresponding interest rates decrease most of the time.

We are interested in how the growth in lending to the corporate sector as well as the average change in the interest rate charged for these loans change in response to changes in capital requirements. We calculate our main measure of bank-specific capital requirements for corporate loans by multiplying a bank's risk-weighted capital requirement ratio by its average risk weight for corporate loans, that is, the risk-weighted assets (RWA) density.

$$\text{cap}_{b,t} = \frac{\text{regCR}_{b,t}}{\text{RWA}_{b,t}} \cdot \frac{\text{RWA}_{b,t}^{\text{corp}}}{\text{TA}_{b,t}^{\text{corp}}} \quad (1)$$

The first term is a bank's total regulatory capital requirement ratio, that is, the sum of minimum pillar 1 requirements, macroprudential capital add-ons including the buffer for SIFIs and the CCoB, and pillar 2 requirements, divided by the bank's total risk weighted assets.<sup>12</sup> The second term—RWA density—is the risk-weighted exposure for the bank's corporate loans relative to the total unweighted exposure for corporate loans. It reflects the average risk weight of the bank's corporate loan portfolio. Hence, our variable  $\text{cap}_{b,t}$  captures a bank's total regulatory capital requirement related to corporate

**Panel A: Changes in corporate loans ( $\Delta$  lending)****Panel B: Changes in corporate loan interest rates ( $\Delta$  interest rate)**

**FIGURE 2** Changes in volume and interest rates of corporate loans. Panel A: Changes in corporate loans ( $\Delta$  lending). Panel B: Changes in corporate loan interest rates ( $\Delta$  interest rate). The figure shows the 25th, 50th and 75th percentile of the quarterly change in corporate loans issued by banks included in the sample (Panel A) as well as the quarterly change in the interest rate charged for these loans (Panel B) from 2008:Q1 to 2018:Q3

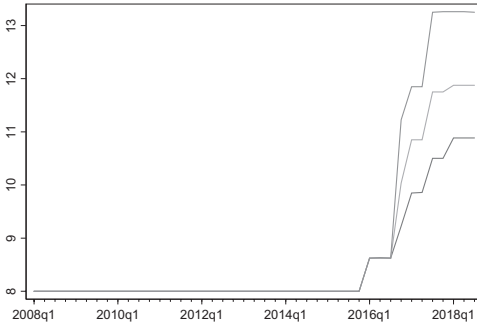
lending. We use this measure rather than the simple regulatory capital requirement ratio because banks with a lower RWA density are relatively less exposed to a change in capital requirements. Accordingly, our measure  $cap_{b,t}$  reflects banks' de facto capital requirements on corporate loans more precisely and accounts for bank's "affectedness" when regulatory requirements change.

Panel A of Figure 3 shows regulatory capital requirements (the first term in Equation (1)) from 2008:Q1 to 2018:Q3 for the banks in our sample. Panel B shows the RWA density for loans to non-financial corporates (the second term in Equation (1)) over time. It measures the "affectedness" of a bank following a change in regulatory capital requirements and includes a substantial degree of heterogeneity across banks as well as over time. Panel C in Figure 3 shows the capital requirement for corporate loans ( $cap_{b,t}$  in Equation (1)) across banks over our sample period. Note that the increase in the average capital requirement from 2015 on is largely attributable to the SREP-related requirements that, along with the SIFI-related add-ons, also create heterogeneity in regulatory requirement ratios across banks. Panel C confirms a substantial degree of variation of our measure of quarterly changes in capital requirements.

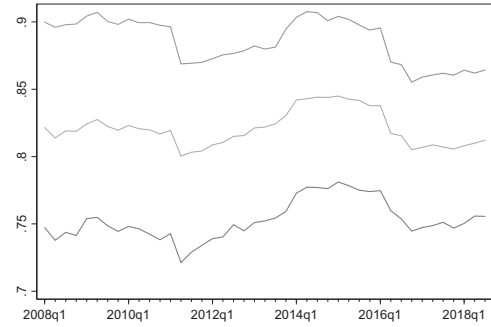
Information on regulatory required capital ratios are publicly available (for minimum requirements, capital conservation and SIFI-related buffers), confidential information on SREP related add-ons are provided by banking supervisors. Further bank-level information is obtained from confidential Bundesbank balance sheet statistics. In our empirical analysis, we control for different relevant bank characteristics and macroeconomic determinants. Bank-specific control variables include a bank's



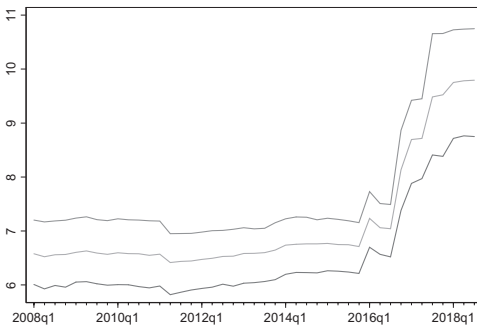
Panel A: Regulatory bank capital requirements



Panel B: RWA density



Panel C: Bank-specific capital requirements



**FIGURE 3** Bank capital requirements. Panel A: Regulatory bank capital requirements. Panel B: RWA density. Panel C: Bank-specific capital requirements. The figure shows the 25th, 50th, and 75th percentile of regulatory bank capital requirements (Panel A), the risk-weighted assets (RWA) density of corporate loans (Panel B), and bank-specific capital requirements for loans to the non-financial corporate sector (Panel C) from 2008:Q1 to 2018:Q3. It reflects the ingredients of  $cap_{b,t} = \frac{regCR_{b,t}}{RWA_{b,t}} \cdot \frac{RWA_{b,t}^{corp}}{TA_{b,t}^{corp}}$  where Panel A shows the first term, Panel B the second term, and Panel C the variable  $cap_{b,t}$ . The first term is a bank's total regulatory capital requirement ratio, i.e., the sum of minimum pillar 1 requirements and other, micro- and macroprudential surcharges (see Section 2.1 of the paper), divided by the bank's total risk-weighted assets. The second term, the RWA density, is the risk-weighted exposure for corporate loans of the bank relative to the total unweighted exposure for corporate loans

size (measured by the logarithm of total deflated assets), the ratio of liquid assets to total assets, the ratio of core deposits to total assets, and the return on assets. We also include a dummy variable for bank mergers which is one in the quarter when a bank merges with another bank and zero otherwise. Macroeconomic control variables are obtained from public sources. All variables are described in more detail in Table 1. Panel A provides summary statistics and Panel B definitions of variables.

Panel A of Table 1 shows that loans to the non-financial corporate sector grow on average by 0.83% in a quarter, while the loan interest rate changes by  $-0.059$  percentage points. The average quarterly change in capital requirements is 0.049 percentage points and the level of excess capital in terms of total assets is 2.762% on average. Our monetary policy stance variable, the 1-year average quarterly change of the money market interest rate is  $-0.058\%$ . Note that this includes both periods with positive and with negative changes, as shown in Figure 1. Banks hold on average 24% liquid assets, have core deposits of 36%, both in terms of total assets, and have a return on assets of 0.20%.

**TABLE 1** Descriptive statistics and description of variables

Variable	Mean	Standard deviation
<i>Panel A: Descriptive statistics</i>		
(1) Dependent variables		
$\Delta$ lending (q-o-q change) (%)	0.826	3.910
$\Delta$ interest rate (q-o-q change) (pp)	-0.059	0.081
(2) Independent variables		
Capital requirements for lending to corporates (change pp)	0.049	0.440
Excess capital (% total assets)	2.762	1.564
Monetary policy stance (change pp)	-0.058	0.233
Bank size (ln real assets)	18.115	1.378
Liquid assets (% total assets)	24.083	12.765
Deposits share (% total assets)	35.732	18.899
RoA (%)	0.197	0.285
Merger dummy	0.003	0.050
Uncertainty	137.662	54.331
Ifo business climate	97.462	5.280
Term spread (change)	-0.012	0.454
Credit-to-GDP gap	-7.241	2.730
GDP gap	0.263	1.570
Variable	Definition	Data source
<i>Panel B: Variable definitions</i>		
(1) Dependent variables		MFI interest rate statistics
$\Delta$ lending	Loans to non-financial corporations in the euro area; % change (q-o-q)	
$\Delta$ interest rate	Weighted interest rate for loans to non-financial corp. in the euro area; change pp (q-o-q)	
(2) Independent variables		
Capital requirements for lending to corporates	Total capital requirements (minimum + combined buffer + pillar 2 requirements); change pp (q-o-q)	COREP, Supervisory data
Excess capital	Minimum of CET1, T1 and T2 excess capital; % of total assets	
Monetary policy stance	Cumulative change in the money market rate (EONIA) over four quarters, pp	ECB
Bank size	Log of total deflated assets	BISTA, FINREP, Solvency statistics
Liquid assets	Sum of cash, balances with the central bank, securities and shares; % of total assets	
Deposits share	Total deposits of the non-financial sector; % of total assets	
RoA	Annual net profit; % of total assets	

**TABLE 1** (Continued)

Variable	Definition	Data source
Merger dummy	Dummy equal to one in the quarter when a merger took place and zero otherwise	Supervisory data
Uncertainty	News based economic policy uncertainty index	Economic Policy Uncertainty (EPU)
Ifo business climate	ifo Business Climate index; 2015 = 100	ifo
Term-spread	Spread between 10-year government bond interest rate and money market rate	ECB
Credit-to-GDP gap	Deviation of credit to GDP from its long-term trend	Bundesbank
GDP gap	Deviation of actual GDP from potential output	Bundesbank

Notes: The table shows descriptive statistics using data from 2008:Q1 to 2018:Q3. Variables are described in Panel B.

## 4 | RESULTS

### 4.1 | Transmission of capital requirements

In a first step, we analyze the relationship between changes in banks' capital requirements and changes in banks' lending and interest rates. We investigate the change of outstanding loans to the non-financial corporate sector as well as the difference in the corresponding lending interest rate of bank  $b$  in quarter  $t$  using the following simultaneous equations regression model:

$$\Delta Y_{b,t} = \alpha_0 + \sum_{k=1}^K \alpha_{1,k} \Delta \text{cap}_{b,t-k} + \beta X_{b,t-1} + f_b + f_t + \varepsilon_{b,t} \quad (2)$$

Note that we use a simultaneous equations approach to account for the possibility that changes in lending and lending rates might be determined simultaneously. It implies that we estimate a system of structural equations. All dependent variables are explicitly taken to be endogenous to the system and are treated as correlated with the disturbances in the system's equations.<sup>13</sup> For identification, we use the first lag of the dependent variables as instruments after having rejected a unit root for these in a Phillips-Perron test and autocorrelation in panel data by a Wooldridge test. This GMM estimator then calculates a weight matrix which is used in the second step of the estimation for the correlation structure of the equation disturbances. The change in a bank's capital requirement is represented by  $\Delta \text{cap}_{b,t-k}$ , with  $K = 4$ . Accordingly, we measure changes in lending and changes in lending rates in response to the changes of a bank's capital requirement over the previous year.  $X_{b,t-1}$  is a vector of lagged bank-specific control variables such as bank size, the ratio of liquid assets to total assets, the ratio of core deposits to total assets, and the return on assets, and an indicator variable for bank mergers included in the same quarter. All regressions include bank fixed effects  $f_b$  and use standard errors clustered at the bank and year-quarter level. The results are shown in Table 2.

Columns (1) and (2) of Table 2 include macroeconomic control variables  $M_t$  such as a measure for economic policy uncertainty, the Ifo business climate, term spread, credit-to-GDP gap, and GDP gap, and columns (3) and (4) year-quarter fixed effects  $f_t$  to account for further unobserved factors varying at the time level. The results show that a change in a bank's capital requirement over the previous year is negatively related to its corporate loan growth. This result is in line with the

**TABLE 2** The effect of changes in bank capital requirements on changes in corporate lending and lending rates

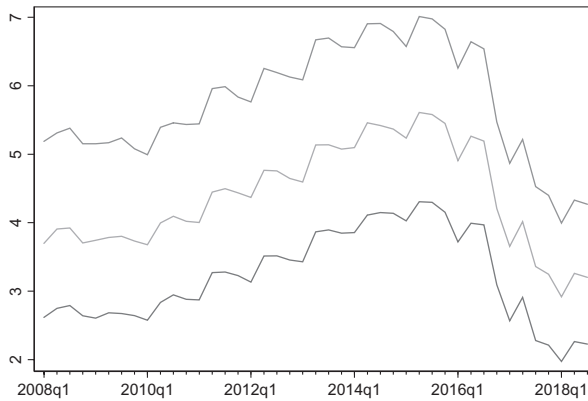
Dependent variable	(1)	(2)	(3)	(4)
	$\Delta$ lending	$\Delta$ interest rate	$\Delta$ lending	$\Delta$ interest rate
$\Delta$ Capital requirement	-1.786*** (3.79E-04)	0.0105 (0.466)	-1.016*** (9.75E-04)	0.004 (0.612)
Bank control variables	Yes	Yes	Yes	Yes
Bank fixed effects	Yes	Yes	Yes	Yes
Macro control variables	Yes	Yes	No	No
Time fixed effects	No	No	Yes	Yes
Observations	5,123	5,123	5,123	5,123
Number of banks	170	170	170	170
$R^2$	0.139	0.224	0.166	0.284

*Notes:* The table shows the second step of two-step GMM regression results of a simultaneous equations estimation regressing the quarterly change in lending to the non-financial private sector and the quarterly change in the average interest rate charged for these loans on the change of a bank's capital requirement and control variables. In the table, columns (1) and (2), and columns (3) and (4) are estimated simultaneously. Columns (1) and (2) show the results for the regressions with macro controls, and columns (3) and (4) the results when using quarter-time fixed effects instead. The data range from 2008:Q1 to 2018:Q3. All variables are used at the bank-quarter level and defined in Panel B of Table 1. For the two-step GMM estimator, the first step estimates each equation via 2SLS using the first lag of the dependent variables as instruments, where a Fisher type unit root test based on the Phillips-Perron test rejects a unit root and a Wooldridge test rejects autocorrelation in panel data in all cases. A weight matrix is then calculated which is used in the second step of GMM. The dependent variables are taken to be endogenous to the system and treated as correlated with the disturbances in the system's equations.  $\Delta$ Capital requirement is shown as the cumulative effect over the previous four quarters. Bank control variables are bank size, liquid assets, deposits share, RoA, all included lagged by one quarter, and a dummy variable which is one in the quarter when a bank merges with another bank. The statistical significance of results is indicated by \* = 10% level, \*\* = 5% level and \*\*\* = 1% level using standard errors clustered at the bank and year quarter level. *p* values are shown in parentheses below coefficient estimates.

findings in, for example, Aiyar et al. (2014), Gropp et al. (2018), and De Jonghe et al. (2020). The coefficient indicates that a 1 percentage point increase in the bank loan type-specific capital requirement results in a 1.8% (1%) decrease in corporate lending when including macroeconomic indicators (year quarter fixed effects) as control variables. Note that our analysis focuses on corporate lending and the corresponding change in interest rates and hence we cannot rule out the possibility that banks shift their lending to other sectors with lower risk weights or lending in other currencies. Table 2 also suggests that capital requirements are not related to changes in lending rates.

The implications of changes in capital requirements might depend on bank characteristics. De Jonghe et al. (2020), for example, show that tighter capital requirements decrease lending more when banks are riskier. Accordingly, the response to changes in bank capital requirements might vary between banks with low and high levels of excess capital, that is, capital above the required regulatory minimum. We calculate a bank's level of excess capitalization using the regulatory definitions for CET1, T1 and T2 capital, in terms of total assets, and use the minimum out of these three. This ensures that we are conservative in our approach given that regulatory compliance differs between these. Figure 4 shows banks' excess capital over our sample period. Excess capitalization increased until 2015 but decreased when the micro- and macroprudential surcharges were implemented until the end of our sample period.

We hypothesize that banks with lower capitalization levels react more strongly to changes in capital requirements. We investigate the effects of changes in capital requirements on loan growth and the change in interest rates by interacting the change in capital requirement with our continuous variable



**FIGURE 4** Excess capital. The figure shows the 25th, 50th, and 75th percentile of banks' excess capital from 2008:Q1 to 2018:Q3. Excess capital is the minimum of a bank's capital above the regulatory requirement, using the definitions for Common Equity Tier 1 (CET1), Tier 1 capital (T1), and Tier 2 capital (T2) for the regulatory requirement. Regulatory capital requirements include the minimum pillar 1 requirements, as well as micro- and macroprudential surcharges (see Section 2.1 of the paper)

of banks' excess level of capital. We estimate the following regression models using, again, our simultaneous equations regression setup for both corporate loan growth and the change in the lending rate.

$$\Delta Y_{b,t} = \alpha_0 + \sum_{k=1}^K \alpha_{1,k} \Delta \text{cap}_{b,t-k} + \sum_{k=1}^K \alpha_{2,k} \Delta \text{cap}_{b,t-k} * \widehat{\text{cap}}_{b,t-1-K} + \alpha_3 \widehat{\text{cap}}_{b,t-1-K} + \beta X_{b,t-1} + f_b + f_t + \epsilon_{b,t} \quad (3)$$

where  $\widehat{\text{cap}}_{b,t-K}$  is a banks' excess capital ratio. Additionally, we split banks by their level of excess capital and estimate the following models using simultaneous equations regressions.

$$\Delta Y_{b,t} = \sum_{k=1}^K \alpha_{1,k} \Delta \text{cap}_{b,t-k}^{\text{low}} + \sum_{k=1}^K \alpha_{2,k} \Delta \text{cap}_{b,t-k}^{\text{high}} + \sum_{k=1}^K \alpha_{3,k} \Delta \text{cap}_{b,t-k} + \beta X_{b,t-1} + f_b + f_t + \epsilon_{b,t} \quad (4)$$

where  $\Delta \text{cap}_{b,t-k}^{\text{low}}$  is the change in capital requirements when in a given year-quarter a bank is in the lowest quartile of the distribution of excess capitalization and zero otherwise, and  $\Delta \text{cap}_{b,t-k}^{\text{high}}$  the change in capital requirements when in a given year-quarter a bank is in the highest quartile.  $K$  is again set to  $K = 4$ . This allows us to test for the differential effects of changes in capital requirement between banks with low and high levels of capitalization using banks with medium capitalization as base effect. Table 3 shows the results.

Panel A of Table 3 shows the results when we interact the changes in capital requirements with our continuous variable of banks' level of excess capital. We observe that the negative relationship between a change in a bank's capital requirement and its corporate loan growth is attenuated by higher levels in excess capital. The coefficients indicate that the effect of changes in bank capital requirements is zero for banks with a level of excess capital to total assets of about 5.6%. Panel B shows our results including the change in capital requirements separately for banks in the lowest and in the highest quartile of excess capital in a quarter.<sup>14</sup> We observe that changes in capital requirements are negatively related only to the loan growth of banks with the lowest capitalization levels. Accordingly, increasing capital requirements imply a decreasing loan growth for weaker banks. Table 3 confirms our previous finding that changes in capital requirements are not related to changes in corporate

**TABLE 3** The effect of changes in bank capital requirements and excess capitalization on changes in corporate lending and lending rates

Dependent variable	(1)	(2)	(3)	(4)
	$\Delta$ lending	$\Delta$ interest rate	$\Delta$ lending	$\Delta$ interest rate
<i>Panel A: Changes in bank capital requirements and their interaction with excess capital</i>				
$\Delta$ Capital requirement	-2.078*** (0.000)	0.012 (0.273)	-2.015*** (0.001)	0.010 (0.520)
$\Delta$ Capital requirement * Excess capital	0.369** (0.007)	0.002 (0.427)	0.298** (0.035)	2.80E-04 (0.426)
Bank control variables	Yes	Yes	Yes	Yes
Bank fixed effects	Yes	Yes	Yes	Yes
Macro control variables	Yes	Yes	No	No
Time fixed effects	No	No	Yes	Yes
Observations	5,051	5,051	5,051	5,051
Number of banks	170	170	170	170
$R^2$	0.134	0.229	0.163	0.286
<i>Panel B: Changes in bank capital requirements splitting banks by low and high excess capital</i>				
$\Delta$ Capital requirement (low excess capital)	-1.251** (0.045)	0.003 (0.849)	-1.425** (0.023)	-0.005 (0.768)
$\Delta$ Capital requirement (high excess capital)	0.189 (0.735)	0.002 (0.893)	0.122 (0.829)	-0.005 (0.759)
Bank control variables	Yes	Yes	Yes	Yes
Bank fixed effects	Yes	Yes	Yes	Yes
Macro control variables	Yes	Yes	No	No
Time fixed effects	No	No	Yes	Yes
Observations	5,051	5,051	5,051	5,051
Number of banks	170	170	170	170
$R^2$	0.168	0.287	0.139	0.225

*Notes:* The table shows the second step of two-step GMM regression results of a simultaneous equations estimation regressing the quarterly change in lending to the non-financial private sector and the quarterly change in the average interest rate charged for these on the change of a bank's capital requirement controlling for the bank's excess capital and control variables. In the table, columns (1) and (2), and columns (3) and (4) are estimated simultaneously. Columns (1) and (2) show the results for the regressions with macro controls, and columns (3) and (4) the results when using quarter time fixed effects instead. The data range from 2008:Q1 to 2018:Q3. All variables are used at the bank-quarter level and defined in Panel B of Table 1. For the two-step GMM estimator, the first step estimates each equation via 2SLS using the first lag of the dependent variables as instruments, where a Fisher type unit root test based on the Phillips-Perron test rejects a unit root and a Wooldridge test rejects autocorrelation in panel data in all cases. A weight matrix is then calculated which is used in the second step of GMM. The dependent variables are taken to be endogenous to the system and treated as correlated with the disturbances in the system's equations.  $\Delta$ Capital requirement is shown as the cumulative effect over the previous four quarters. Excess capital is defined as a bank's capital above its regulatory requirement, divided by the bank's total assets. In Panel A, Excess capital is included as base effect but omitted from the table. In Panel B, a bank's capital requirement is interacted with the indicator variable low (high) excess capital which is one when a bank is in the lowest (highest) quartile of the distribution of excess capitalization in a quarter and zero otherwise.  $\Delta$ Capital requirement is included as a base effect but omitted from the table. Bank control variables are bank size, liquid assets, deposits share, RoA, included lagged by one quarter, and a dummy variable which is one in the quarter in which a bank merges with another bank. The statistical significance of results is indicated by \* = 10% level, \*\* = 5% level and \*\*\* = 1% level using standard errors clustered at the bank and year quarter level. *p* values are shown in parentheses below coefficient estimates.

lending rates. A deeper analysis would require data at the loan level, which we do not have available, and may provide an interesting avenue for future research.

## 4.2 | Transmission of capital requirements and monetary policy

In this section, we additionally investigate the effect of euro area monetary policy on corporate loan growth and changes in lending rates. In our sample period, monetary policy was largely accommodative, as confirmed in Figure 1. The bank lending channel was the target of several monetary policy measures. In addition to the change in capital requirements we, therefore, incorporate a measure for the monetary policy stance using the cumulative change in the money market rate over the previous three and the current quarter.<sup>15</sup> That is, we estimate the following regression model using again our simultaneous equations setup for both corporate loan growth and the change in the lending rate

$$\Delta Y_{b,t} = \alpha_0 + \sum_{k=1}^K \alpha_{1,k} \Delta \text{cap}_{b,t-k} + \alpha_2 \sum_{l=0}^L \Delta \text{MP}_{t-l} + \beta X_{b,t-1} + \gamma M_t + f_b + \epsilon_{b,t} \quad (5)$$

with  $\Delta \text{MP}_{t-l}$  indicating the cumulative change in our monetary policy variable, and  $L = 3$ . Note that we are not able to include year-quarter time fixed effects  $f_t$  in these regressions as they would absorb our monetary policy variable due to missing variation within a year quarter. Instead, we include our set of macro control variables  $M_t$ . We additionally split banks by their level of excess capitalization using the upper and lower quartile in terms of bank capitalization in a quarter, comparable to our split in Panel B of Table 3. We are interested whether differential effects between more and less capitalized banks also exist with respect to monetary policy changes. Panel A of Table 4 shows the results.

Panel A confirms our previous finding. We observe that changes in capital requirements are negatively related to banks' corporate loan growth, and that this is driven by banks with lower levels of excess capital. The table also shows that the monetary policy stance is related to bank lending. Panel A of Table 4 suggests that the euro area monetary policy is positively related to changes in corporate lending rates. The results imply that a 1 percentage point decrease in the money market rate reduces the change in interest rates by about 0.14 percentage points. While we do not observe a relationship of monetary policy to loan growth in the aggregate, splitting banks by their capitalization levels reveals that accommodating monetary policy is related to an increasing loan growth of banks with high excess capitalization.<sup>16</sup>

As mentioned earlier, monetary policy was largely accommodative in our sample period. However, we observe several periods where the average change in the money market rate was increasing, indicating a monetary policy tightening.<sup>17</sup> To explore whether the effect is symmetric in episodes of tightening and easing monetary policy, we split our monetary policy variable into two parts. *Monetary policy [easing]* is the cumulative change in the money market rate when it is negative and zero otherwise. *Monetary policy [tightening]* is the cumulative change when it is greater than zero.<sup>18</sup> We again estimate Equation (5) in our simultaneous equations regression design but replace  $\Delta \text{MP}_{t-l}$  with these two variables. Panel B of Table 4 shows the results.

Regarding corporate loan interest rates, we find our previous result confirmed for both, a tightening and an easing of euro area monetary policy. Changes in the policy rate are positively correlated with changes in corporate lending rates. This implies that an accommodative monetary policy stance translates into lower corporate lending rates while tighter monetary policy implies higher corporate lending rates. Note that the coefficients between our monetary policy variables are not directly comparable in their relation to lending rates as the average decrease in the money market rate ( $-0.36$ ), as well as its standard deviation ( $0.78$ ), is much larger than its average increase ( $0.15$ ) and deviation

**TABLE 4** The effect of changes in bank capital requirements and monetary policy on changes in corporate lending and lending rates

Dependent variable	All banks		Low excess capital banks		High excess capital banks	
	(1)	(2)	(3)	(4)	(5)	(6)
	$\Delta$ lending	$\Delta$ interest rate	$\Delta$ lending	$\Delta$ interest rate	$\Delta$ lending	$\Delta$ interest rate
<i>Panel A: Changes in bank capital requirements and monetary policy</i>						
$\Delta$ Capital requirement	-0.870*** (0.002)	0.014* (0.081)	-1.627*** (0.005)	0.023 (0.171)	0.431 (0.476)	0.017 (0.343)
Monetary policy	-0.868 (0.123)	0.136*** (0.000)	-0.608 (0.622)	0.116*** (0.001)	-1.948* (0.081)	0.084** (0.010)
Bank control variables	Yes	Yes	Yes	Yes	Yes	Yes
Bank fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Macro control variables	Yes	Yes	Yes	Yes	Yes	Yes
Observations	5,123	5,123	1,168	1,168	1,344	1,344
Number of banks	170	170	92	92	80	80
$R^2$	0.138	0.234	0.213	0.286	0.135	0.204
<i>Panel B: Changes in bank capital requirements and monetary policy by easing and tightening</i>						
$\Delta$ Capital requirement	-0.912*** (0.002)	0.00622 (0.442)	-1.64*** (0.004)	0.021 (0.210)	0.39 (0.520)	0.39 (0.520)
Monetary policy [easing]	-0.736 (0.194)	0.154*** (0.000)	-0.532 (0.667)	0.137*** (0.000)	-1.984* (0.077)	0.110*** (0.001)
Monetary policy [tightening]	2.130 (0.223)	0.723*** (0.000)	2.106 (0.587)	0.776*** (0.000)	0.174 (0.960)	0.663*** (0.000)
Bank control variables	Yes	Yes	Yes	Yes	Yes	Yes
Bank fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Macro control variables	Yes	Yes	Yes	Yes	Yes	Yes
Observations	5,123	5,123	1,168	1,168	1,344	1,344
Number of banks	170	170	92	92	80	80
$R^2$	0.139	0.257	0.214	0.308	0.135	0.223

*Notes:* The table shows the second step of two-step GMM regression results of a simultaneous equations estimation regressing the quarterly change in lending to the non-financial private sector and the quarterly change in the average interest rate charged for these on the change of a bank's capital requirement and the monetary policy interest rate and control variables. In the table, columns (1) and (2), columns (3) and (4), and columns (5) and (6) are estimated simultaneously. Columns (3) and (4) ((5) and (6)) include *low (high) excess capital banks* defined as bank in the lowest (highest) quartile of the distribution of excess capitalization in a quarter. Panel A shows the results for the regressions with macro controls, and Panel B the results when using quarter-time fixed effects instead. The data range from 2008:Q1 to 2018:Q3. All variables are used at the bank-quarter level and defined in Panel B of Table 1. For the two-step GMM estimator, the first step estimates each equation via 2SLS using the first lag of the dependent variables as instruments, where a Fisher type unit root test based on the Phillips-Perron test rejects a unit root and a Wooldridge test rejects autocorrelation in panel data in all cases. A weight matrix is then calculated which is used in the second step of GMM. The dependent variables are taken to be endogenous to the system and treated as correlated with the disturbances in the system's equations.  $\Delta$ Capital requirement is shown as the cumulative effect over the previous four quarters. *Monetary policy* is the level of the money market interest rate which is shown as the joint average effect over the current and the previous three quarters. In Panel B, *Monetary Policy* is interacted with indicator variables which are one when the money market interest rate declines (*Monetary Policy [easing]*) and when it increases (*Monetary Policy [tightening]*) from month<sub>t-3</sub> to month<sub>t</sub>. *Bank control variables* are bank size, liquid assets, deposits share, RoA, all included lagged by one quarter, and a dummy variable which is one in the quarter when a bank merges with another bank. The statistical significance of results is indicated by \* = 10% level, \*\* = 5% level and \*\*\* = 1% level using standard errors clustered at the bank and year quarter level. *p* values are shown in parentheses below coefficient estimates.



(0.33) in our sample period. However, accounting for these differences still shows that the sensitivity with respect to corporate interest rate changes is larger for a tightening of monetary policy. Regarding loan growth, we again find our previous result confirmed that accommodating monetary policy is related to an increasing loan growth of banks with high excess capitalization. Interestingly, column (5) in Panel B shows that banks with high levels of excess capital seem to increase their lending when the money market rate decreases. This may indicate that better capitalized banks are better transmitters of accommodative monetary policy, in line with the results in Acharya et al. (2020). However, we refrain from interpreting this result in more detail as the coefficient is only marginally significant.

Overall, the results in this section confirm that changes in capital requirements are negatively related to the loan growth of weaker banks, while accommodating monetary policy is related to an increasing loan growth of banks with high excess capital. It suggests that banks' capital constraints are important for the transmission of changes in capital requirements as well as monetary policy. Furthermore, our results show that changes in euro area monetary policy are positively correlated with the corporate loan interest rates charged by banks, irrespective of their level of capitalization.

### 4.3 | Transmission of capital requirements, monetary policy, and their interaction

In this section, we examine whether the interaction between changes in capital requirements and the monetary policy stance is related to banks' lending. We use our regression setup from Panel B of Table 4 but additionally interact the change in capital requirements with our variables *Monetary policy [easing]* and *Monetary policy [tightening]*. We again investigate the results for the total sample as well as separately for the two subsamples of banks with low and high levels of excess capital. The results are shown in Table 5.

Table 5 confirms our previous findings on the transmission of policy changes. Changes in capital requirements are negatively related to the loan growth of banks with lower levels of excess capital, accommodative monetary policy is related to an increasing loan growth of banks with high excess capital, and euro area monetary policy changes are positively correlated with corporate lending rates. As to the interaction between changes in capital requirements and monetary policy, we only observe effects with respect to corporate loan interest rates. Changes in capital requirements in the opposite direction to the monetary policy interest rate have countervailing effects to the transmission of monetary policy on lending rate changes. Both coefficients for our interaction terms are opposite to the positive correlation of monetary policy to banks' interest rates. This implies that a decreasing (increasing) policy rate is associated with lower (higher) corporate lending rates; however, when capital requirements simultaneously increase (decrease), this relationship is attenuated. This result is largely confirmed when we split banks into those with high and with low levels of excess capital. The only exception is the coefficient of the interaction term between changes in capital requirement and stricter monetary policy for banks with low excess capital, which is also negative but statistically insignificant.

In sum, changes in the euro area monetary policy stance are related to changes in corporate lending rates in the same direction, irrespective of bank capitalization. However, simultaneous but opposite changes in capital requirements might attenuate this transmission. While this might be desirable from a policy perspective when monetary policy is tightened, it might also counteract monetary policy intentions when the policy is accommodative. Importantly, changes in capital requirements are additionally related to the loan growth of weaker banks and an easing of monetary policy implies a higher loan growth of better capitalized banks. This suggests that since the financial crisis, when monetary policy was largely

**TABLE 5** The effect of changes in bank capital requirements and monetary policy conditional on bank capitalization corporate lending and lending rates

Dependent variable	All banks		Low excess capital banks		High excess capital banks	
	(1)	(2)	(3)	(4)	(5)	(6)
	$\Delta$ lending	$\Delta$ interest rate	$\Delta$ lending	$\Delta$ interest rate	$\Delta$ lending	$\Delta$ interest rate
$\Delta$ Capital requirement	-0.615* (0.056)	0.003 (0.765)	-1.340** (0.044)	0.002 (0.915)	0.297 (0.648)	0.004 (0.822)
Monetary policy [easing]	-0.885 (0.119)	0.171*** (0.000)	-0.552 (0.655)	0.137*** (0.000)	-2.710** (0.015)	0.122*** (0.000)
Monetary policy [tightening]	1.441 (0.417)	0.745*** (0.000)	1.836 (0.649)	0.753*** (0.000)	-0.334 (0.925)	0.625*** (0.000)
$\Delta$ Capital requirement * MP [easing]	2.677 (0.105)	-0.086* (0.058)	0.760 (0.763)	-0.154** (0.036)	-7.177 (0.207)	-0.328** (0.045)
$\Delta$ Capital requirement * MP [tightening]	-10.08 (0.285)	-0.546** (0.039)	-12.61 (0.531)	-0.597 (0.307)	-1.133 (0.953)	-1.146** (0.040)
Bank control variables	Yes	Yes	Yes	Yes	Yes	Yes
Bank fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Macro control variables	Yes	Yes	Yes	Yes	Yes	Yes
Observations	5,123	5,123	1,168	1,168	1,344	1,344
Number of banks	170	170	92	92	80	80
R <sup>2</sup>	0.140	0.263	0.218	0.322	0.157	0.238

*Notes:* The table shows the second step of two-step GMM regression results of a simultaneous equations estimation regressing the quarterly change in lending to the non-financial private sector and the quarterly change in the average interest rate charged for these on the change of a bank's capital requirement and the monetary policy interest rate by easing and tightening periods and their interaction and control variables. In the table, columns (1) and (2), columns (3) and (4), and columns (5) and (6) are estimated simultaneously. Columns (3) and (4) ((5) and (6)) include *low (high) excess capital banks* defined as bank in the lowest (highest) quartile of the distribution of excess capitalization in a quarter. The data range from 2008:Q1 to 2018:Q3. All variables are used at the bank-quarter level and defined in Panel B of Table 1. For the two-step GMM estimator, the first step estimates each equation via 2SLS using the first lag of the dependent variables as instruments, where a Fisher type unit root test based on the Phillips-Perron test rejects a unit root and a Wooldridge test rejects autocorrelation in panel data in all cases. A weight matrix is then calculated which is used in the second step of GMM. The dependent variables are taken to be endogenous to the system and treated as correlated with the disturbances in the system's equations.  $\Delta$ Capital requirement is shown as the cumulative average effect over the previous four quarters. Monetary policy (MP) is the level of the money market interest rate which is shown as the joint average effect over the current and the previous three quarters and interacted with indicator variables which are one when the money market interest rate declines (*Monetary Policy [easing]*) and when it increases (*Monetary Policy [tightening]*) from month<sub>t-3</sub> to month<sub>t</sub>. Bank control variables are bank size, liquid assets, deposits share, RoA, all included lagged by one quarter, and a dummy variable which is one in the quarter when a bank merges with another bank. The statistical significance of results is indicated by \* = 10% level, \*\* = 5% level and \*\*\* = 1% level using standard errors clustered at the bank and year quarter level. *p* values are shown in parentheses below coefficient estimates.

accommodative and at the same time bank capital requirements increased, banks' capital constraints induced a differential loan growth between weaker and stronger banks due to the effects of both policies, while banks' lending rates might have decreased to a smaller extent than intended by policymakers.

## 4.4 | Further robustness checks

To explore the sensitivity of our results to changes in the sample and time period, we perform a set of robustness checks. All robustness checks re-estimate Equation (5) for a distinct subsample.

Some banks in our sample operate subsidiaries outside Germany or the EU, and therefore their operations, abroad as well as at home, may be affected by regulatory changes in other jurisdictions. In order to ensure that our results are not affected by this, we exclude all banks with foreign subsidiaries from our sample. We find that the negative relationship between increases in capital requirements and lending, as well as the positive relationship between monetary policy changes and lending rates are confirmed.

During the earlier years of our sample period other factors, such as capital losses and ensuing difficulties to raise capital or liquidity shocks, may have affected bank lending and lending rates to a substantial degree. We, therefore, re-estimate our main model excluding the financial crisis and use a sample period from only 2010q1 to 2018q3. Again, we find our main results confirmed.

## 5 | CONCLUSION

This paper explores the transmission of bank capital requirements and monetary policy as well as their joint effect on banks' lending to the non-financial corporate sector in the euro area. The results suggest that, for weakly capitalized banks, increases in capital requirements are negatively associated with immediate changes in lending, but not with lending rates. The relationship is economically significant as an increase of regulatory capital requirements of 1 percentage point is associated with a 1.7 percentage point decrease in euro area bank lending growth. This effect is observable only for banks operating close to the regulatory required level of capital, and it disappears for banks with excess capital to total assets ratios of around 6 percent or higher. Our results do not show a relationship between capital requirements and corporate lending rates. Changes in the monetary policy stance are positively related to corporate loan interest rates in general, and an increasing loan growth of strongly capitalized banks when the stance is accommodating. These findings suggest that the immediate transmission of changes in capital requirements as well as in the monetary policy stance to corporate loan growth hinge on the level and the distribution of bank capitalization in a banking system.

Our sample period of 2008 to 2018 is predominantly characterized by increases in capital requirements. At the same time, the euro area monetary policy stance was mostly accommodative. The interaction between the two policies only affects banks' lending through loan interest rates. While changes in the monetary policy interest rate translate into changes of loan interest rates in the same direction, contemporaneous changes of capital requirements in the opposite (same) direction attenuate (reinforce) the general effects of monetary policy on interest rates. These findings suggest that a careful and elaborate mutual consideration of both monetary policy and bank capital regulation is crucial for ensuring the policies' efficacy.

Overall, our results may help policymakers to gauge *ex ante* the domestic as well as international implications of policy actions, and identify and gauge possible undesired immediate externalities. Besides, the results point toward the need for monitoring not only the policy actions of international financially integrated countries, but also certain features of the respective foreign banking systems and its main lenders. Finally, this study provides crucial indications for analyses of the aggregate effects of policy changes, which are beyond the scope of our analysis. Future work exploring aggregate policy effects should account for how determining features, such as banks' excess capitalization, and their distribution is related to the distribution of, for instance, lending volumes.

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## ENDNOTES

- <sup>1</sup> In this paper, the terms “bank interest rate,” “lending interest rate,” and “interest rate” are used synonymously. All terms refer to the bank- and time-specific weighted interest rate for outstanding lending to corporates in the euro area and denominated in Euro.
- <sup>2</sup> Examples are Bernanke and Blinder (1992), Kashyap, Lamont, and Stein 1994, Kashyap and Stein (1995, 2000), Gambacorta and Mistrulli (2004), Jiménez, Ongena, Peydro, and Saurina (2012), or Acharya, Imbierowicz, Steffen, and Teichmann (2020).
- <sup>3</sup> Mankart, Michaelides, and Pagratis (2020) show that tighter leverage requirements *ceteris paribus* (c.p.) increase lending to sectors with higher risk weights, while higher risk-weighted capital requirements c.p. reduce banks’ loan supply.
- <sup>4</sup> Note that this might be specific to our sample period (2008:Q1 to 2018:Q3) with only few periods of monetary policy tightening.
- <sup>5</sup> See Vandenbussche, Vogel, and Detragiache (2015) for a study of a comprehensive set of prudential policy measures. Other studies accounting for the intensity of policy changes focus on LTV changes only.
- <sup>6</sup> In the EU, Basel III has been implemented with the Capital Requirement Directive (CRD IV) and the Capital Requirement Regulation (CRR), which form the European legal framework. CRD IV provisions require implementation in the German Banking Act (Kreditwesengesetz - KWG).
- <sup>7</sup> See Budnik and Kleibl (2018) and the related MaPPED for details on all macroprudential policy actions in the EU between 1995 and 2014.
- <sup>8</sup> For an extensive overview of euro-area monetary policy, see Hartmann and Smets (2018).
- <sup>9</sup> In robustness tests, we use both shadow rates and monetary policy surprises as our measures of monetary policy interest rates with the caveat that we do not have them available over our entire sample period. Results are qualitatively confirmed.
- <sup>10</sup> For more detailed information see: <https://www.bundesbank.de/resource/blob/604796/d52dbf21479d4be76e0afd0d3d50e7bb/mL/research-data-micro-data-zista-2017-data-report-data.pdf>.
- <sup>11</sup> We focus on lending to the non-financial corporate sector for several reasons. First, lending to the real economy is most closely related to economic growth. Second, risk weights for these corporate loans are readily available and frequently updated. And third, a larger fraction of corporate loans has shorter maturities and accordingly better (in terms of delay) reflects changes in capital requirements and monetary policy.
- <sup>12</sup> Banks have to comply with these requirements differently. While minimum capital requirements are hard requirements, that is, mandatory, a breach of the capital buffer would only trigger automatic restrictions on dividend and bonus payments a bank can make.
- <sup>13</sup> Our approach is comparable to that of Imbierowicz et al. (2018) who investigate changes in capital requirements and their effects on banks’ capital and lending decisions.
- <sup>14</sup> All regressions in Panel B of Table 3 include the change in capital requirement as base effect which is not reported for brevity. The coefficients are statistically insignificant in all cases.
- <sup>15</sup> We rerun all our analyses using the loan interest rate spread over the money market rate instead of the loan interest rate. The results are qualitatively the same.
- <sup>16</sup> We also re-rerun all regressions excluding the changes in capital requirements. All results continue to hold.
- <sup>17</sup> As an example, the ECB increased its main refinancing rate from 100 to 125 bps on April 13, 2011 and further to 150 bps on July 13, 2011, which is also reflected in our monetary policy measure.

<sup>18</sup> Note that the cumulative change over the last three and the current quarter is not zero in any quarter of our sample period.

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