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ELIF C. ARBATLI-SAXEGAARD
RAGNAR E. JUELSRUD

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Countercyclical capital requirement reductions, state dependence and macroeconomic outcomes *

Elif C. Arbatli-Saxegaard† and Ragnar E. Juelsrud‡

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Abstract

We use bank-, loan- and firm-level data together with a quasi-natural experiment to estimate the impact of capital requirement reductions on bank lending and real economic outcomes. We find that capital requirement reductions increase lending both to households and firms at the bank- and loan-level, and that the increased lending to firms translates into higher capital investment at the firm-level. Furthermore, the transmission of lower capital requirements to the real economy has a "double state-dependence". The first state-dependence relates to the characteristics of banks. Specifically, the transmission of lower capital requirements to lending is *stronger* for banks with lower capital ratios. We interpret this result as capital requirement reductions having a larger effect when they are more binding. The second state-dependence relates to the characteristics of the corporate sector. Specifically, the transmission of lower capital requirements to real economic outcomes - via bank lending - is *weaker* for firms with higher default risk or more leverage, suggesting that capital requirement reductions is most effective in terms of boosting real economic outcomes when firms are financially sound.

JEL-codes: E51, G21, G28

Keywords: Banking, capital requirements, macroprudential regulation.

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†*Elif C. Arbatli-Saxegaard*: Norges Bank, Financial Stability Department, elif.arbatli@norges-bank.no

‡Corresponding author: *Ragnar E. Juelsrud*: Norges Bank, Research Department, ragnar.juelsrud@norges-bank.no

1 Introduction

Financial crises that are preceded by strong credit growth are often associated with severe recessions (Schularick and Taylor (2012) and Jordà et al. (2013)). An important component of the new international regulatory framework aimed at reducing the probability and severity of financial crises (Basel III) is the counter-cyclical capital requirement (Basel Committee on Banking Supervision (2010a)). The counter-cyclical capital buffer is built up during financial booms and is reduced in downturns when banks face losses. The key objective of the buffer is to reduce the risk that the supply of credit is constrained during an economic downturn, ultimately undermining the performance of the real economy. The relevance of countercyclical capital requirements as a potential tool for macroeconomic stabilization has become evident recently as several countries have lowered capital requirements in an attempt to stimulate lending following the Covid-19 outbreak.

While there is a relatively large and growing literature on the banking sector and the real effects of *increases* in capital requirements (see for instance Gropp et al. (2019) or Juelsrud and Wold (2019)), there is much less evidence on the effectiveness of capital requirement *reductions* and in particular on their effects during periods of deteriorating macroeconomic conditions.[1] Understanding the effectiveness of reducing capital requirements is critical for evaluating the potency of time-varying capital requirements as a macroeconomic stabilization tool. Estimating the effect of capital requirement reductions on lending and real economic outcomes is complicated, however, for multiple reasons. First, historically there are only a few instances when capital requirements were reduced. For instance, the counter-cyclical capital buffer was introduced in several countries but was lowered only recently after the onset of the Covid-19 epidemic. Second, capital requirement reductions are typically endogenous to factors which ultimately affect bank outcomes and the real economy through other channels, such as a decline in demand.[2]

In this paper, we use administrative and supervisory bank-, loan- and firm-level data to investigate the impact of capital requirement reductions on credit and real economic outcomes. Our empirical analysis focuses on the lending response of a subset of Norwegian banks during their transition from Basel I to Basel II in 2008. Under Basel II, the risk-weights for banks not employing internal ratings based risk models ("non-IRB banks") were reduced for certain exposures, leading to a lower capital requirement. The capital requirement reduction was large, corresponding to a reduction in the required capital adequacy ratio of about 1 percentage point on average. Moreover, the decrease was a function of banks' initial portfolios which ultimately resulted in considerable variation in capital requirement reductions across banks. We refer to this capital requirement reduction as a "capital release". The transition to Basel II, by coincidence, coincided with the onset of the financial crisis, a negative macroeconomic shock which originated outside of Norway

[1] Moreover, estimates of the effects of capital requirement increases are not necessarily useful for understanding how capital requirement *reductions* affect the economy. Increases in capital requirements may work differently than decreases in capital requirements. For example capacity to raise external capital and bank profitability may be important factors when capital requirements are increased but not as important when requirements are reduced.

[2] For instance, capital requirement reductions are often implemented as a macroeconomic support measure and hence correlated with negative demand shocks ultimately affecting firms' demand for credit and performance.

and affected the Norwegian economy through international spillovers. Norwegian banks' transition to Basel II therefore provided an almost ideal laboratory to analyse how banks may respond to capital requirement reductions during economic downturns.

We use data from three different sources. First, bank-level data are obtained from a supervisory database covering all Norwegian banks and a large set of balance sheet items at a quarterly frequency. Since the capital requirement reduction was a function of detailed bank balance sheet characteristics, this data is necessary to properly measure the treatment intensity of the Basel II transition at the bank-level. For each bank, we compute the reduction in capital requirement due to the Basel II transition. We complement this database with an administrative loan-level data-set, covering the universe of Norwegian firms. This data-set allows us to provide further evidence that the capital release led to a credit supply expansion by using information on both quantities and prices, as well as by controlling for firm-specific factors that can proxy for demand effects. Finally, we merge the loan-level data with a third database, where we observe all major balance sheet and income statement data at the firm level, allowing us to trace the effects of capital requirement reductions on firm investment. Our combined database runs over the period between 2005 and 2009, and covers the universe of non-IRB Norwegian banks, all of their corporate loans and contains information on all firms that have a banking relationship with them.

Our baseline identification strategy is to compare the evolution of bank-, loan- and firm-level outcomes according to banks' capital release in a difference-in-differences setting. The identifying assumption we make is that the outcomes we consider would have been similar for banks with different capital releases or firms borrowing from banks with different capital releases absent the Basel II transition. We perform several robustness tests to ensure that other confounding factors do not drive our findings.

We present three sets of results. First, we find that the capital requirement reduction led to an expansion of bank balance sheets and a broad-based increase in lending at the bank-level, financed by increased debt. The semi-elasticity of lending is sizable, suggesting that a one percentage point reduction in the capital requirement expands overall lending growth by 7.7 percentage points, household lending growth by 4.4 percentage points and non-financial corporate lending growth by 13 percentage points. At the loan-level, the fact that the latter arises from a credit supply expansion rather than a contemporaneous increase in credit demand is corroborated by lower interest rates in addition to higher quantities. The increase in corporate lending is driven by an expansion of credit both at the intensive and the extensive margins. Moreover, banks do not only respond to the decrease in capital requirements by increasing lending. They also invest more in financial assets such as short-term bonds and central bank deposits. As a result of the balance sheet expansion, bank profits go up.

Second, the increase in lending leads to more favorable real economic outcomes. Firms borrowing from banks experiencing a larger reduction in the capital requirement, faces a relaxed external financing premium, which ultimately results in higher growth in dividend payouts and capital investment. A one percentage point decrease in the capital requirement at the bank-level translates into a 7.5 percentage point higher growth in capital investment at the firm-level.

Third, the strength of the transmission of lower capital requirements to lending and real economic outcomes has two key layers of state-dependence. The first state-dependence relates to bank characteristics. Banks with lower initial equity ratios increase lending more, conditional on having the same capital release. This is consistent with capital requirements being a non-negligible constraint on lending prior to the Basel II transition. We also find that effects of capital requirement reductions on lending is higher among banks with lower losses or higher reliance on inter-bank funding.

The second state dependence relates to firm characteristics. We find that the increase in credit is driven by firms with low initial leverage and default risk. The same firms transmit the expansion in credit to higher dividend payouts and higher capital investment. Our results therefore suggest that the macroeconomic effects of lower capital requirements depend on the state of the real economy and that it is most effective when the creditworthiness of the firms is relatively high.

2 Related Literature

Our paper relates to a growing literature that studies the effects of capital requirements. Fraisse et al. (2020) use variation in internal risk models among French banks, and document significant effects on corporate lending from increasing risk-weighted capital requirements. Aiyar et al. (2014) compare credit provision by resident foreign branches and domestic UK banks, tracing the effects of time-varying bank-specific capital requirements that applied to the latter group. Gropp et al. (2019) study the impact of higher capital requirements on banks' balance sheets using the 2011 EBA capital exercise as a quasi-natural experiment.[3] Juelsrud and Wold (2019) use bank- and loan-level data for Norway, focusing on the 2013 Norwegian policy reform to study how banks react to higher capital requirements and how these adjustments affect the real economy.

A relatively small number of papers consider the effects of capital requirement *reductions*. Jimènez et al. (2016) use Spain's experience with dynamic provisioning to study the effects of counter-cyclical adjustments in loss provisioning. The authors exploit the bank specific nature of the requirements and bank-firm level data to study the effects of both increases and decreases in capital requirements. They find that in good times, a higher need for provisioning leads to lower credit supply but that the effects are short-lived. In downturns, they find that a one percentage point increase in capital buffers boost lending to firms by nine percent and firm employment by six percent, and lead to a one percentage point increase in firm survival. Another paper that is closely related to ours is Imbierowicz et al. (2018), which analyze the Basel II transition in Denmark and focus on the bank-specific time-varying hard capital requirements that were imposed by the regulator. They find that banks adjust to capital requirement increases by adjusting risk-weights, while capital requirement decreases lead to higher lending. Finally, Brun et al. (2013) also use the transition to Basel II and exploit the switch from capital charges that was common across all firms under Basel I to firm- and bank-specific capital charges for IRB-banks under Basel II. Their results confirm large effects of capital requirements on bank

[3] See also Basel Committee on Banking Supervision (2010b) on the effects of higher capital requirements.

lending - a one percentage point decrease in capital requirement leads in their study to an increase in loan size by about 5 percent.[4]

Our empirical exercise differs from these studies in at least three ways. First, we focus on the effects of a reduction in banks' *capital requirement*, which can be different from the effects of having higher *capital buffers* as examined in Jimènez et al. (2016). In Brun et al. (2013) capital requirements are not defined at the bank level but rather at the bank-firm level reflecting the fact that they exploit differences across banks' internal rating models. Second, in both Imbierowicz et al. (2018) and Jimènez et al. (2016), changes in capital requirements depend to a larger extent on bank characteristics that may be relevant in considering the effects of capital on lending. For example, in Imbierowicz et al. (2018) changes in capital requirements are determined for each bank by regulators. In Jimènez et al. (2016), capital buffers depend on banks' lending growth and level of specific provisions across different asset classes. In our paper, the reduction in capital requirements depend on the pre-Basel II composition of bank assets according to a few broad asset categories. As such, the reduction in capital requirements is plausibly orthogonal to individual bank losses or provisions and other measures of bank risk. Finally, our bank-, loan and firm-level analysis allows us to jointly study the effects of capital requirement reductions on firm-level outcomes and how banks adjust their balance sheets when capital requirements are reduced. Jimènez et al. (2016) focus on the former question, while Imbierowicz et al. (2018) focus on the latter.

3 Introduction of Basel II in Norway

The Basel II accord was published in 2004 and aimed to amend international capital requirements to make banks' capital allocation more risk-sensitive. The transition changed how banks compute risk-weighted assets and entailed lower capital requirements for all banks but to a varying extent. The previous regulation, Basel I, had a coarse set of risk-weights attributed to different types of loans. The effect of Basel II transition on risk-weights differed depending on the method for calculating risks-weights. First, banks were allowed to apply for using the so-called Internal Ratings Based (IRB) approach, which entailed client-specific risk-weights based on banks' own models of credit risk. Banks that did not apply to use the IRB approach - non-IRB banks - faced a similar split of assets into different risk bins as before, but the risk-weights for some asset classes were reduced. Most Norwegian banks continued to use the standardised approach and transitioned to Basel II at the beginning of 2008.[5]

[4]In addition to these papers, Dietsch et al. (2019) and Mayordomo and Rodríguez-Moreno (2018) investigate the impact of lower capital requirements for SMEs and document an increase in credit supply. Our paper differs from these studies in the sense that we are not analyzing a capital requirement reduction targeted at increasing credit to a specific subset of firms.

[5]Basel II framework for capital regulation became effective in Norway from the 1st of January 2007. Most IRB banks transitioned to Basel II during 2007, while almost all non-IRB banks transitioned at the beginning of 2008.

Table 1: Changes in risk-weights under Basel II for standard method banks.

Loan type	Basel II risk-weight	Basel I risk-weight
Mortgage (LTV<0.8)	35%	50%
Other exposures in retail portfolio[1)]	75%	100%

1) The retail portfolio consists of mortgage loans, other loans to households and some of the loans to small enterprises.

The changes in risk-weights for the non-IRB banks due to Basel II transition are summarized in Table 1.[6] Mortgages with a loan-to-value less than 80 percent and certain other retail loans (typically corporate retail loans) were assigned a lower risk-weight under Basel II. For all other assets, the risk-weights remained unchanged. As a result, the Basel II transition led to cross-sectional variation in the change in capital requirements among non-IRB banks reflecting differences in banks' pre-Basel II composition of assets.

Our focus in this paper is on evaluating the impact of lower capital requirements due to the change in risk-weights for non-IRB banks. We focus on non-IRB banks for two reasons. First, the sample of non-IRB banks in Norway is significantly larger compared to the sample of IRB banks. This offers a greater degree of variation in the change in capital requirement due to lower risk weights across banks, which is critical for our empirical strategy.[7]

Second, there were important differences in how Basel II was phased in for IRB and non-IRB banks. For the IRB banks, the decline in risk-weights were restricted by the imposition of a transitional floor, which dampened the initial reduction in IRB banks' capital requirements.[8] For the non-IRB banks, on the other hand, the reduction in capital requirements were immediately realized in 2008.

The downside of using only the non-IRB banks is that they constitute a smaller share of total lending in Norway. Non-IRB banks constituted roughly 22% of lending to corporate sector and 40 % of lending to households in 2006. However, non-IRB banks are disproportionately important for small, bank-dependent firms. Almost half (43%) of all credit relationships in 2006 were with non-IRB banks. While the non-IRB banks are different from IRB banks in many respects, the non-IRB banks were broadly representative of the total domestic banking sector during our period of analysis in terms of outcomes such as lending growth.

[6]Basel II also implemented a capital requirement for operational risk. The capital requirement due to operational risk typically constituted around 5% of the total change in the capital requirements, and we abstract from that here.

[7]There were only 7 banks that were approved to use the IRB approach as of 2008, while the rest of the banks operating in Norway (more than 130 of them) continued to use the standardised approach. These banks represented approximately 43 % of all corporate lending relationships in 2006.

[8]See Andersen et al. (2020) for an analysis of the impact of the Basel II transition on the IRB-banks.

4 Methodology and data

In this section, we outline the details of our empirical approach. We start by describing the data, before explaining how we exploit the Basel II transition as a source of cross-sectional variation in capital release. We then discuss our econometric implementation, potential threats to identification and how we address them.

4.1 Data

We use data from three different sources. We start by using quarterly supervisory bank balance sheet data on all non-IRB banks and their associated credit companies in Norway. This data-set covers up to 140 banks and includes information on loans, assets, equity and profits. After documenting how banks adjust their balance sheets in response to decreased capital requirements, we proceed by using a loan level data-set provided by the Norwegian Tax Authorities. This data-set contains annual, matched firm-bank data for the universe of Norwegian firms. The tax data has several advantages. First, it allows us to observe the entire portfolio of domestic corporate credit for all Norwegian banks. This enables us to do a more granular analysis of how banks respond. For example, using this loan-level database it is possible to observe credit extension both at the intensive and extensive margins. Second, it strengthens identification by allowing us to control for various firm-factors. Using the tax data, we can also observe the interest paid on loans. This enables us to study the price effects of the reform by constructing an interest rate proxy for each loan.[9] Third, it allows us to study firm-level effects of lower capital requirements, including profits and investment which we obtain from our third data source, a firm-level data-set covering all corporations in Norway.

Summary statistics for the three datasets we use are reported in Table 2.

4.2 Capital release due to Basel II

Banks in our data does not report the capital requirement for the same portfolio under Basel II and Basel I directly. In order to quantify the bank-level capital release as a result of the Basel II-transition, we therefore compute the average risk-weight $\overline{\alpha}^{i}_{b,2006q4}$ under Basel II rules and Basel I rules ($i \in \{\text{Basel I}, \text{Basel II}\}$) for each bank b. In order to calculate the average risk-weight, we use data on banks' balance sheet composition as of 2006q4.[10] In our bank-level data, we observe balance sheet data that is sufficiently granular to compute the exact capital release for each bank, with two exceptions. First, we do not have bank-level data on the LTV breakdown of the mortgage portfolio. This is important, since the risk-weight was only lowered for low LTV mortgages. However, we do have the aggregate LTV distribution of mortgages in our sample. In expectation, this should therefore also represent the LTV distribution at the bank-level. We therefore assume a similar breakdown between high-LTV and low-LTV mortgages across all banks. Second, risk-weights were also reduced for *retail* corporate loans. We do not observe those loans in our data at the bank-level, but we have an estimate for non-IRB banks as a whole. We therefore follow a similar approach as we did for the high- versus

[9] We compute the interest rate proxy by interest paid divided by the outstanding debt balance.

[10] Our results are robust to computing the capital release using balance sheet composition in 2004 when Basel II was first announced.

Table 2: Summary statistics

Variable	N	Mean	Std. Dev.	Min	Max
		Banks			
Capital release	140	0.01	0.001	0	0.012
Δ log(All loans)	4301	0.03	0.04	-0.11	0.42
Δ log(Mortgages)	4301	0.03	0.06	-0.65	0.84
Δ log(NFC loans)	4187	0.03	0.14	-3,85	2,31
Δ log(Total assets)	4301	0.03	0.06	-0.65	0.84
Δ log(Fin.assets)	3595	0.04	0.31	-9.25	7.94
Δ log(Equity)	3842	0.02	0.20	-6.63	5.52
Δ log(Profit)	3683	0.09	0.96	-6.10	6.74
Δ RoA Ratio	3862	0.0002	0.005	-0.05	0.04
		Loans			
$\tilde{\Delta}$ $L_{f,b,t}$	242806	-0.04	0.64	-2	2
Interest rate	302924	0.06	0.05	0.00	1.00
New relationship	302924	0.20	0.39	0	1
		Firms			
Δ log(Fin. assets)	61775	0.06	1.00	-10.44	11.58
Δ log(dividends)	131684	0.15	2.37	-15.85	15.55
Δ log(sales)	91982	0.06	0.67	-10.69	9.30
Δ log(capital)	116749	0.01	0.60	-10.02	7.61
Δ log(wages)	91021	0.09	0.63	-8.42	8.37

Notes: This table shows summary statistics for our bank- (top), loan- (middle) and firm-level data. All summary statistics are computed from 2005 - 2009. Δ represent quarterly changes in the bank-level data, and annual changes in the firm-level data. $\tilde{\Delta}$ represents annual symmetric change. New relationship is a dummy equal to 1 if the relationship is present in year t but not in year $t-1$.

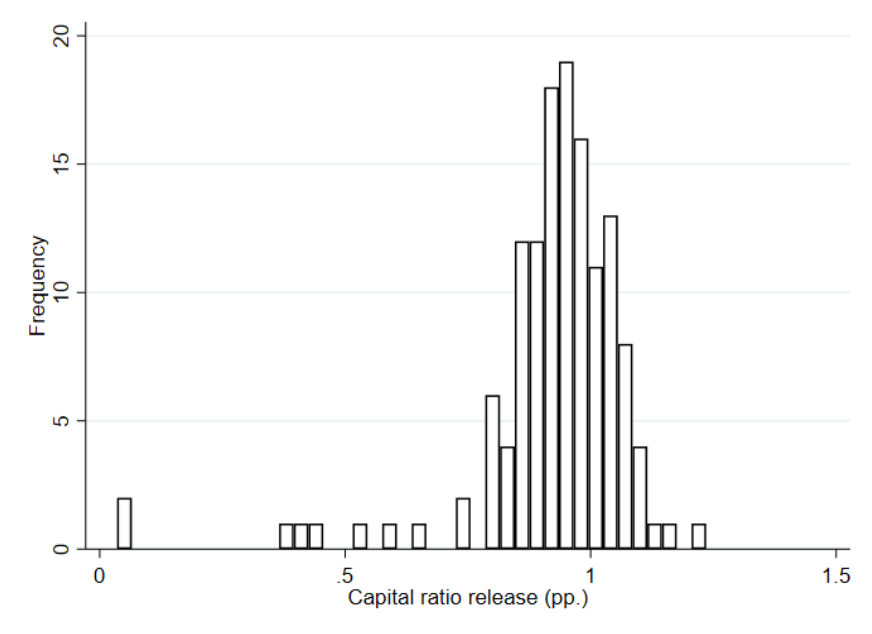

Figure 1: Predicted capital release

Notes: This figure shows the distribution of capital releases due to the Basel II transition, computed from equation (1).

low-LTV mortgages, and assume that the share of retail corporate loans to total corporate loans is similar across banks. This leaves us with a noisy proxy of the risk-weight change at the bank-level as a consequence of the Basel II transition.

With our balance sheet data and the two assumptions outlined above, we can then compute the capital release for each bank using the following formula:

$$\text{Capital release}_{b,2006q4} = \kappa \times \left(\overline{\alpha}^{\text{Basel I}}_{b,2006q4} - \overline{\alpha}^{\text{Basel II}}_{b,2006q4} \right) \tag{1}$$

The capital release equals the difference in average risk-weights under Basel I and Basel II multiplied by the minimum capital ratio requirement (κ) ("headline capital requirement").[11] The capital release variable is interpreted as the reduction (in percentage points) of bank b's capital requirement as a consequence of the Basel II transition. The distribution of bank-level capital releases is shown in Figure 1.

Two observations are worth making. First, the average capital release is relatively large, corresponding to approximately 1 percentage point (Table 2). This corresponds to a reduction in headline capital requirement of about 2 percentage points assuming an average risk-weight of 50 percent for Norwegian banks. Second, its variation across banks is quite large. While the capital release is always positive, some banks experience a very low capital release while others experience capital releases well above 1 percentage point. The variation in capital release across banks is primarily driven by variation in the mortgage share, although there is also

[11] The headline capital requirement used in calculating the capital release is 8 percent.

sizable variation in the corporate share across banks.[12]

There are two important caveats with using the Basel II transition as a laboratory for understanding the efficacy of lower capital requirements as a countercyclical macroprudential tool. First, our estimates will reflect the effects of a permanent capital release. If banks expect capital requirements to be increased later, their incentives to expand lending may be reduced. This suggests that estimates using the Basel II transition as an empirical strategy may be an upper bound for the effects of capital requirement reductions that are more transitory in nature. Also, since some risk-weights were reduced especially for mortgages, the Basel II transition likely induced a relative shift to mortgage credit. However, as we show in the empirical analysis, it also lead to an increase corporate credit.

Second, our results will reflect a reduction in "hard" capital requirements, whereas the capital buffers built up after the financial crisis are to a large extent constituted of "soft" requirements.[13] While one would expect the effects of reducing soft capital requirements to be lower than the effects of reducing hard capital requirements, there is no indication that banks treat the Basel III capital buffers as easily usable. Market pressure is one reason for why banks may individually find it very costly to use their regulatory capital buffers.

4.3 Empirical strategy and identification

Our empirical strategy involves estimating a relationship between the bank-specific capital release and different economic variables of interest. In doing this, we use both dynamic and static difference-in-differences models. The dynamic difference-in-differences model we use is given by (2):

$$\Delta log(Y_{i,t}) = \alpha + \sum_{\tau} \delta_{\tau} \mathbf{1}_{t=\tau} + \sum_{\tau} \gamma_{\tau} \times \left(\text{Capital release}_{b,2006q4} \times \mathbf{1}_{t=\tau} \right) + \epsilon_{i,t} \tag{2}$$

where $Y_{i,t}$ is a bank-, loan- or firm-level outcome of interest at time t, α is bank-firm-year fixed-effects (depending on specification), δ_{τ} are coefficients for time-dummies and $\epsilon_{i,t}$ are standard errors clustered at the bank- or firm-level.[14] γ_{τ} is an estimate of the relationship between the Basel II capital release and outcome Y at time τ, conditional on the fixed-effects.

In the static version of our model, we assume a constant relationship between the capital release and the outcome of interest for the pre- and post-Basel II periods, instead of estimating a period-by-period slope with respect to the capital release. The coefficient of interest β in equation (3) is then interpreted as an average treatment effect over the Basel II transition period.

$$\Delta log(Y_{i,t}) = \alpha + \sum_{\tau} \delta_{\tau} \mathbf{1}_{t=\tau} + \beta \left(\text{Capital release}_{b,2006q4} \times I_t^{post} \right) + \epsilon_{i,t} \tag{3}$$

[12] The standard deviation of the mortgage share is 13 percentage points, while the standard deviation of the corporate share is 5 percentage points.

[13] Soft requirements can be temporarily violated under certain conditions.

[14] The capital release is always at the bank-level, irrespective of whether we focus on the bank-, loan- or firm-level.

We estimate equations (2) and (3) using different variables of interest at the bank-, loan- and firm-level. For firm-level variables, the capital release is computed as the average across a firm's all banking connections.[15]

4.3.1 Threats to identification

Our identifying assumption is that bank-, loan- and firm-level outcomes would have been similar for banks with different capital releases or firms borrowing from banks with different capital releases absent the transition to Basel II. There are at least four threats to the validity of this identifying assumption.

Systematic differences The first threat to identification is that banks with different capital releases are structurally different in terms of outcomes. For instance, if banks with a high predicted capital release have higher and increasing lending growth compared to other banks throughout our sample period, we would estimate a positive and significant effect of the capital release on lending growth.

An advantage with the empirical specification in equation (2) is that it allows us to directly test for this by estimating period-specific "treatment" effects also prior to the transition. Specifically, we can explore if there were parallel trends among banks with different capital releases prior to the transition by testing if $\gamma_\tau = 0 \; \forall$ $\tau < 0$, using $\tau = 0$ to capture the start of the Basel II transition.

Confounding demand shocks The second threat to identification is that, even if banks with different capital releases are similar prior to the transition, they may have experienced different demand shocks during the Basel II transition. This is a concern, as the Basel II transition coincided with the financial crisis where firms may have been affected by different shocks. Shocks to the corporate clients of banks could affect our results if firms and banks are systematically linked. In that case differences in credit growth between banks of different capital releases could be a result of different demand shocks rather than the decline in capital requirements.

In order to alleviate this concern, we exploit the structure of our loan-level data to control for different firm characteristics to ensure that we compare outcomes for relatively similar firms. Using our loan-level data we also investigate the impact of capital release on loan-level interest rates. While negative demand and supply shocks have similar effects on quantities, they have different effects on prices. We therefore investigate differences in loan-pricing across banks with different capital releases to strengthen our inference further.[16]

Confounding supply shocks A third threat to identification could arise if there are other factors that affect banks' supply of credit that are correlated with the capital release. For instance, it could be that banks with different levels of capital release have a different degree of direct exposure to the global financial crisis, for

[15] We restrict attention to only consider firms with no relationships to IRB banks.

[16] A standard approach in the literature for identifying supply side effects is to use firms with multiple bank relationships to control for firm specific demand effects (Khwaja and Mian, 2008). In our loan-level database, approximately 5 percent of firms borrow from at least two different non-IRB banks and therefore this approach does not give us a sufficient source of variation. As an alternative approach, we add firm and (two-digit) industry× year fixed effects to control for time-invariant firm factors and factors that are constant within industry × year.

example because they have different exposures to the U.S mortgage market. Most of the non-IRB banks in our sample are not internationally active, and we therefore believe this is less of a concern.

An important factor which could have affected credit supply however, is the tightening of liquidity conditions during the crisis and the liquidity support measures that were provided by the central bank and the government. If banks that experienced a relatively high capital release happen to be less affected by the tightening in liquidity, we could have misinterpreted our results as capturing the effects of lower capital requirements. Conversely, if banks that benefited more from the liquidity support measures also happened to have received a higher capital release, we could have overestimated the effects of capital release.

Another potential factor affecting relative credit supply could be the anticipation of higher future capital requirements or at least a reversal of the capital release following the Basel II transition.

We conduct two robustness exercises to tackle these concerns. First, we include a proxy for banks′ liquidity shock exposure as a control and an interaction in our bank-level analysis. Second, we re-estimate all of our empirical models focusing on the period before Lehman Brothers collapsed and before the support programs were put in place as well as any international discussion of future regulatory changes.

Finally, there could be other indirect effects of the financial crisis on banks' supply of credit. There is for instance some evidence that the internationally active IRB banks which were more directly affected by the crisis retrenched credit in certain regions. This provided an opportunity for more regionally focused non-IRB banks to expand their market share. The fact that the Basel II transition potentially was relatively stricter for IRB banks due to the IRB-floor discussed in Section 3 could also contribute to a competitive advantage for non-IRB banks. In order to tackle this concern, we use the granularity of our data to investigate - at the regional level - the pre-crisis presence of IRB banks in the regional markets of non-IRB banks, and how it correlates with the capital release. A strong positive relationship between pre-crisis IRB presence and the capital release at the bank-level would be a cause for concern, whereas no relationship or a negative relationship would suggest that these alternative hypotheses are less of a concern.

Anticipation effects A final concern is that treated banks according to our measures adjusted prior to the implementation of the Basel II transition. This is a valid concern, as the Basel II transition was communicated well in advance of 2007/2008. Note that such anticipation effects are likely to lead us to underestimate the effects of the capital release. Moreover, the flexible difference in differences allow us to explicitly map out *when* treated banks adjust relative to the actual capital release and hence we can be somewhat agnostic about the exact timing of the reform.

5 Banks adjustment to lower capital requirements

In this section, we present our main empirical results related to banks response to the capital release. We start by investigating how the capital release following the Basel II transition affected credit supply, considering both bank- and loan-level outcomes. A key take-away is that lower capital requirements lead to more lending both at the bank and the loan level. We then explore the underlying mechanisms behind our

findings, and show that our results are driven by banks with low initial capital ratios. We then explore how banks adjust other components of their balance sheets. We find that lower capital requirements lead to an overall expansion of banks' balance sheets, rather than a substitution from other assets to lending.

5.1 Effect of capital release on lending

We first consider the dynamic treatment effects of the capital release on total lending as captured by γ_τ in equation (2). The estimated coefficients are shown in Figure 2. After the Basel II transition in 2008, the dynamic treatment effects are positive, suggesting that banks with a higher capital release increased lending more relative to other banks. Figure 2 shows that this effect is larger throughout 2008 and the beginning of 2009, and statistically significant in 2008q4 and 2009q1.[17] Moreover, the dynamic treatment effects plotted in Figure 2 show that the capital release due to Basel II is not associated with credit growth prior to the Basel II transition. We interpret this as validation of our "parallel trends" assumption.

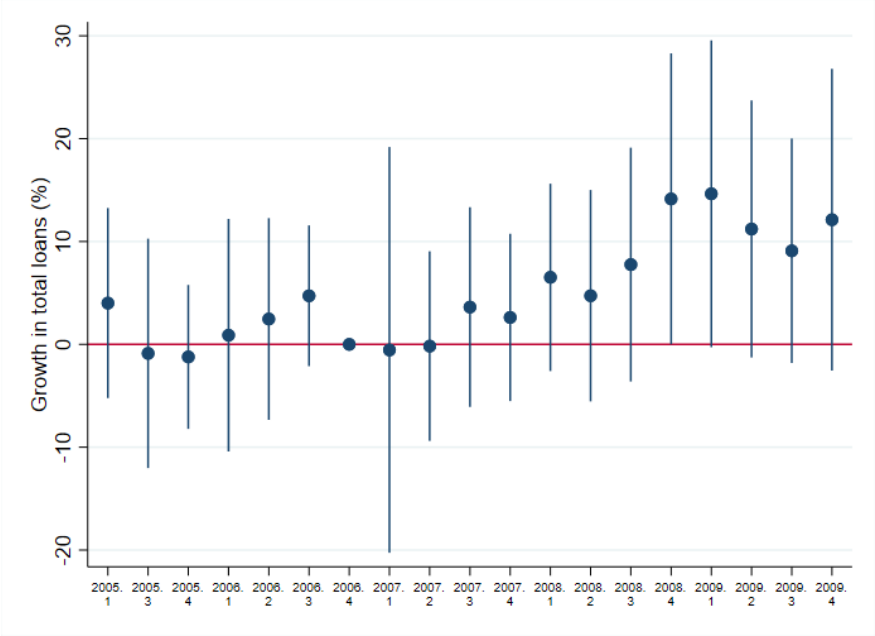

Figure 2: Capital release and overal lending growth

Notes: This figure shows the dynamic treatment effects (γ_τ) after estimating equation (2). Circles indicate point estimates, and vertical lines represent the 95% confidence interval. All coefficients are plotted relative to 2006q4.

We next consider the average treatment effects of the capital release in 2008 and 2009, captured by the coefficient β in equation (3). Consistent with the dynamic treatment effects in Figure 3, banks with a higher capital release increase lending more after the Basel II transition (column (1) in Table 3). On average, a one percentage point higher capital release (constituting a 2 percentage point reduction in headline risk-weighted capital requirement based on an average risk-weight of 50 percent) increases lending growth by 7.7 percentage

[17]The difference in 2009q1 is significant at the 90% level.

points. This is economically sizable: a one standard deviation increase in the capital release leads to a 0.37 standard deviation higher growth in credit.

Table 3: Bank-level results

	(1) ΔLog(Total loans)	(2) ΔLog(Mortgages)	(3) ΔLog(NFC loans)
$\text{Post}_t \times \text{Capital release}_{b,2006q4}$	7.743***	4.371***	12.99***
	(2.250)	(1.559)	(4.771)
N	3821	3821	3778
No. of clusters	132	132	132
Mean of dependent variable	0.0282	0.0264	0.0284
SD of dependent variable	0.0348	0.0400	0.131
Mean of capital release	0.00921	0.00921	0.00921
SD of capital release	0.00160	0.00160	0.00160
Bank FE	Yes	Yes	Yes
Year-quarter FE	Yes	Yes	Yes

Notes: * p<0.1, ** p<0.05, ***p<0.01. Mean and standard deviations are taken over the full sample period (2005 - 2009). Post = 1 for 2008 and 2009, and zero otherwise. Standard errors clustered at the bank level.

Next, we focus on two sub-components of lending: mortgages and lending to non-financial corporations. Columns (2) and (3) in Table 3 present results where growth in mortgage lending and lending to non-financial corporations are used as the dependent variables, respectively. The capital release has a positive and significant effect on both components of lending, suggesting that the increase in lending documented in Column (1) and Figure 2 is driven by a broad-based increase in lending not particular to either the household or the corporate sector. A one standard deviation increase in the capital release is associated with a 0.16 standard deviation increase in mortgage lending growth and a 0.2 standard deviation increase in lending growth to non-financial corporations.

We next consider the impact of capital release on lending using loan-level data, where we focus exclusively on lending to non-financial corporations. We report our estimates of the average treatment effects based on regression (3) in Table 4. The estimate in column (1) indicates that the positive association between bank-level capital release and corporate lending also extends to loan-level data. According to the estimated coefficient, a one percentage point higher capital release at the bank-level leads to approximately 8.7 percentage point higher credit growth at the loan-level.

Table 4: Loan-level results

	(1) Credit growth	(2) Interest rate	(3) New relationship = 1
$\text{Post}_t \times \text{Capital release}_{b,2006q4}$	8.726***	-0.488***	29.69***
	(2.946)	(0.158)	(5.550)
N	67349	86120	86120
No. of clusters	98	98	98
Mean of dependent variable	-0.0302	0.0618	0.161
SD of dependent variable	0.602	0.0464	0.368
Mean of capital release	0.00709	0.00709	0.00709
SD of capital release	0.00245	0.00245	0.00245
Bank FE	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Firm industry x Year FE	Yes	Yes	Yes

Notes: * p<0.1, ** p<0.05, ***p<0.01. Mean and standard deviations are taken over the full sample period (2005 - 2009). Post = 1 for 2008 and 2009, and zero otherwise. Standard errors clustered at the bank level.

In column (2), we consider the relationship between bank-level capital release and loan-level interest rates. Our point estimate is negative and statistically significant, consistent with the capital release leading to an expansion of credit supply.

A relevant question is whether the capital release following the Basel II transition also led to a credit supply expansion along the extensive margin. In column (3), we re-estimate equation (3) with a dummy equal to 1 if the observed loan is to a new client and zero otherwise. A higher capital release at the bank-level increases the incidence of new relationships significantly. A one percentage point increase in capital release increases the likelihood of a loan being to a new client by approximately 29 basis points, suggesting that the capital release also has a statistically significant impact on credit provisioning at the extensive margin.

5.2 Where does the credit go?

Next, we explore whether the corporate credit supply expansion documented in the previous section is broad-based, i.e. banks expand credit to all firms, or whether more affected banks target specific type of customers. Whether a reduction in capital requirements affect all or only some firms are theoretically unclear ex.ante. If banks' credit allocation can be represented as a portfolio choice problem, i.e. as in Kim and Santomero (1988) or Juelsrud and Wold (2019), a theoretical prediction is that a relaxation of capital requirements leads to a broad-based increase in lending, provided that the risk-weight on individual assets is proportional to the systematic risk of a loan.

More generally, however, coarse risk-weights and costly equity implies that banks can have incentives to shift credit once the capital requirement is relaxed. A large literature emphasizes how bank risk increases in response to relaxed financial conditions (Buch et al., 2014; Jiménez et al., 2014).[18] One explanation for this

[18]This finding is not universal, however. Andrade et al. (2019) documents how the expansion of long-term liquidity in the LTRO

empirical finding is that at least certain banks can have incentives to target riskier borrowers (i.e a "search for yield"), as documented in for instance Jimènez et al. (2016).

On the other hand, an emerging literature has focused on how, empirically, low-risk firms are more responsive to monetary policy accommodation (Ottonello and Winberry, 2018) in the US. The underlying mechanism here is that the marginal cost curve associated with increased credit for a risky firm is steeper compared to a safe firm, and safe firms therefore typically have greater scope for expansion when credit conditions ease.[19] Similar mechanisms could be at play when capital constraints on banks are relaxed. Specifically, a general increase in credit supply can materialize in terms of large credit quantity increases for safer firms, whereas it materialize primarily in higher risk premia for riskier firms.

We therefore proceed by investigating whether the increase in lending growth documented in Table 4 arises across all firms, or whether it is driven by certain groups of firms. In line with the literature discussed in the preceding paragraphs and following Ottonello and Winberry (2018), we partition firms based on proxies for solvency and leverage. Since most firms in our data are non-listed, we compute a simple z-score as a measure of default risk.[20] In addition to our measure of default risk, we also partition firms based on a simple leverage ratio.

Table 5: Loan-level heterogeneity

	(1) Credit growth	(2) Credit growth	(3) Credit growth	(4) Credit growth	(5) Credit growth
$\text{Post}_t \times \text{Capital release}_{b,2006q4}$	8.726***	13.63***	2.353	13.25***	5.170
	(2.946)	(4.228)	(4.135)	(4.629)	(3.190)
N	67349	30798	28054	28011	30923
No. of clusters	98	95	97	95	97
Mean of dependent variable	-0.0302	-0.0552	-0.00797	-0.0587	-0.00839
SD of dependent variable	0.602	0.605	0.571	0.613	0.567
Mean of capital release	0.00709	0.00709	0.00709	0.00709	0.00709
SD of capital release	0.00245	0.00245	0.00245	0.00245	0.00245
Bank FE	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes
Firm industry x Year FE	Yes	Yes	Yes	Yes	Yes
Sample	All	Low default risk	High default risk	Low leverage	High leverage

Notes: * p<0.1, ** p<0.05, ***p<0.01. Mean and standard deviations are taken over the full sample period (2005 - 2009). Post = 1 for 2008 and 2009, and zero otherwise. Standard errors clustered at the bank level. Column (1) considers the full sample. Columns (2) and (3) consider sub-samples of firms with a 2006 (inverse) z-score below and above the median, respectively. Columns (4) and (5) consider sub-samples of firms with a 2006 leverage ratio below and above the median, respectively.

Our main conclusion from this analysis, shown in Table 5, is that the loan-level increase in lending is stronger for the group of firms with low default risk and low leverage. This is consistent with banks' allocating

program of ECB did not lead to an expansion is risk.

[19] Even though monetary policy accommodations affects the credit worthiness of all borrowers through general equilibrium effects and thereby "flattens" the marginal cost curve for all firms, less risky firms respond more empirically.

[20] The z-score is defined as the average return on assets over the last 4 years plus the equity ratio of the firm, divided by the standard deviation of return on assets over the last 4 years. For interpretability, we invert the z-score so that an increase is interpreted as an increase in default risk.

credit towards low-risk borrowers. At least based on the proxies we consider, there are no clear indications that the expansion in credit is consistent with a search for yield.

5.3 Which banks respond to the capital release?

In the previous section, we documented how a decrease in capital requirements induces an increase in lending to high-quality borrowers. In this section, we explore whether the effect of capital release on lending depends on bank characteristics.

We consider how the impact of a capital release depend on bank characteristics by estimating average treatment effects using bank-level data as in equation (3) and adding an interaction term for different bank characteristics.[21] The interaction terms depend on the equity ratio, bank size (log of total assets), return on total assets, write-offs relative to total assets and inter-bank borrowing relative to assets.[22]

Table 6: Heterogeneous effects

	(1) Δ log(All loans)	(2) Δ log(All loans)	(3) Δ log(All loans)	(4) Δ log(All loans)	(5) Δ log(All loans)
$\text{Post}_t \times \text{Capital release}_{b,2006q4}$	16.22***	-6.01	8.19	10.15***	8.96***
	(2.20)	(19.38)	(5.52)	(3.88)	(3.13)
$\text{Post}_t \times \text{Capital release}_{b,2006q4} \times \text{Equity/Assets}_{b,2007q4}$	-104.0***				
	(20.8)				
$\text{Post}_t \times \text{Capital release}_{b,2006q4} \times \text{Log(Assets)}_{b,2007q4}$		0.86			
		(1.28)			
$\text{Post}_t \times \text{Capital release}_{b,2006q4} \times \text{RoA}_{b,2007q4}$			-21.61		
			(540.25)		
$\text{Post}_t \times \text{Capital release}_{b,2006q4} \times \text{Writeoffs/Assets}_{b,2007q4}$				831.45*	
				(442.26)	
$\text{Post}_t \times \text{Capital release}_{b,2006q4} \times \text{Interbank loans/Assets}_{b,2007q4}$					12.15**
					(4.84)
N	3,786	3,786	3,786	3,557	3,204
Clusters	130	130	130	121	110
Bank FE	Yes	Yes	Yes	Yes	Yes
Year-quarter FE	Yes	Yes	Yes	Yes	Yes

Notes: * p<0.1, ** p<0.05, ***p<0.01. Standard errors are clustered at the bank-level. This table shows the results from estimating equation (3) using the log-change in total loans and interacting the $Post_t \times$Capital release variable with equity/total assets, the log of total assets, RoA and write-offs to total assets and inter-bank borrowing to total assets, respectively. All interaction terms are measured by the end of 2007. $\text{Post}_t = 1$ for 2008 and 2009 and zero otherwise. Means and standard deviations taken over the whole sample period (2005 - 2009).

We conclude that there are three main factors that are important for understanding how lower capital requirements affect lending (see Table 6). First, the effect of lower capital requirements is muted for banks with higher equity ratios. Put differently, low-capitalized banks respond more to a reduction in capital requirements compared to high-capitalized banks. This suggests that the capital requirement prior to Basel II transition was a non-negligible constraint on bank behavior and that the capital release indeed captures a positive credit supply shock. Second, banks subject to more liquidity risk, proxied by a large inter-bank exposure, also respond more to a reduction in the capital requirement. This suggests that exposure to liquidity constraints and capital requirements have reinforcing effects. Third, banks with larger write-offs respond less to a reduction in capital requirements. This is consistent with models of debt overhang, where banks

[21] Bank characteristics are based on end-2007 values.

[22] Write-offs are weakly negative and bounded above by 0.

with larger latent losses abstain from profitable investments, as it represents a transfer to debt-holders.[23] We emphasize, however, that the effect is imprecisely estimated.

5.4 Effect of capital release on other bank-level outcomes

We next explore whether banks responded to the capital release by adjusting other margins in addition to their lending behavior. The results from estimating equation (3), but with a wide range of other bank outcomes such as total assets and profits are reported in Table 7.

Table 7: Bank-level results

	(1) ΔLog(Total assets)	(2) ΔLog(Fin. assets)	(3) ΔLog(Equity)	(4) ΔLog(Liabilities)	(5) ΔLog(Profit)	(6) ΔRoA
$\text{Post}_t \times \text{Capital release}_{b,2006q4}$	4.227***	21.58**	-9.929	5.088**	32.05***	0.138*
	(1.548)	(9.262)	(10.08)	(1.959)	(10.76)	(0.0779)
N	3821	3248	3435	3442	3308	3442
No. of clusters	132	130	132	132	132	132
Mean of dependent variable	0.0264	0.0371	0.0223	0.0281	0.0838	0.000209
SD of dependent variable	0.0400	0.186	0.0970	0.0444	0.970	0.00443
Mean of capital release	0.00921	0.00921	0.00921	0.00921	0.00921	0.00921
SD of capital release	0.00160	0.00160	0.00160	0.00160	0.00160	0.00160
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes
Year-quarter FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: * p<0.1, ** p<0.05, ***p<0.01. Mean and standard deviations are taken over the full sample period (2005 - 2009). Post = 1 for 2008 and 2009, and zero otherwise. Standard errors clustered at the bank level.

Consistent with the capital release leading to an overall expansion of the banks' balance sheets, rather than a substitution from other assets to lending, total assets grow more for banks with a higher capital release. The economic magnitude of the asset-response is somewhat smaller compared to lending response, but still sizable: A one standard deviation increase in capital release leads to a 0.15 standard deviation increase in growth in total assets. This effect is roughly comparable in absolute value compared to the estimated effects of a capital requirement increase on a relatively similar sample (Juelsrud and Wold, 2019). The capital release also leads to an expansion in financial assets (column 2). This is consistent with the additional lending being matched by additional holdings of liquid assets. Furthermore, we find no clear indication that banks respond to the relaxation of capital requirements by reducing their equity.[24] Hence, our results suggests that lower capital requirements is met by an expansion of banks' balance sheet, rather than a reduction in equity or a shift in the composition of assets, which is confirmed by higher growth in liabilities (column (4)).

Finally, we consider the overall impact on profits and return on assets (columns (5) and (6)). Consistent with a larger balance sheet, bank profits increase. There are some indications that this is also the case when measured relative to total assets, i.e. that the marginal loans are more profitable, but this effect is imprecisely measured.

[23] See for instance Gropp et al. (2019) for empirical evidence of the relevance of debt overhang in the context of banking.

[24] A sizable fraction of our banks are savings banks which do not pay dividends, hence there is likely limited scope for banks to reduce their equity in response to the capital release.

6 Lower capital requirements and real economic outcomes

In the previous sections, we documented a sizable lending response of banks to the capital release. At the loan-level, the growth in corporate credit was driven by an increase in lending for firms with low leverage and low default risk.

A natural question is whether this expansion of credit lead to more favorable real economic outcomes. In this section, we therefore investigate whether the reduction in capital requirements affect real economic outcomes. We do so by focusing on the performance and behavior of the corporate sector. For identification, we investigate whether firms borrowing from a bank with a relatively larger capital release experience different outcomes compared to other firms.

Specifically, we aggregate our data to the firm-level and estimate equation (3) using a broad range of firm outcomes as dependent variable. We focus on the growth in several balance sheet items (holdings of financial assets and capital), employment demand (as proxied with the wage bill), output (as proxied with sales) and dividend payouts. The results are reported in Table 8.

Table 8: Firm-level results

	(1) ΔLog(Fin. assets)	(2) ΔLog(Dividends)	(3) ΔLog(Sales)	(4) ΔLog(Capital)	(5) ΔLog(Wages)
$\text{Post}_t \times \text{Capital release}_{b,2006q4}$	6.311	40.17***	2.043	7.006***	2.247
	(4.302)	(10.58)	(1.734)	(1.741)	(2.901)
N	20562	47222	32707	41783	32045
No. of clusters	97	97	96	97	97
Mean of dependent variable	0.0682	0.156	0.0649	0.0177	0.0866
SD of dependent variable	0.977	2.281	0.624	0.573	0.608
Mean of capital release	0.00713	0.00713	0.00713	0.00713	0.00713
SD of capital release	0.00235	0.00235	0.00235	0.00235	0.00235
Bank FE	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes

Notes: * p<0.1, ** p<0.05, ***p<0.01. Mean and standard deviations are taken over the full sample period (2005 - 2009). Post = 1 for 2008 and 2009, and zero otherwise. Standard errors clustered at the firm-level.

Our estimates indicate that the credit expansion due to the capital release translates into more favorable real economic outcomes at the firm-level. Specifically, firms borrowing from banks with a larger capital release have larger capital investments (column (4)). Moreover, they increase dividend payouts, consistent with a relaxation in the external finance premium. We find no significant effect on firms' financial assets, sales or wage costs. The economic magnitudes are muted but not negligible - a 1 standard deviation increase in the capital release at the bank-level translates into a 0.03 standard deviation increase in firm-level growth in capital expenditures.

To provide further evidence that the increase in capital investment documented in Table 8 is indeed driven by the increase in credit, we explore if our results are only present for low risk/low leverage firms, i.e. the firms experiencing an increase in credit supply. We therefore re-estimate our empirical model using the

same sub-samples as in Table 5.

The results shown in Table 9 suggest that the effect of capital release on capital expenditures (column (1)) is indeed driven by firms with low default risk (column (2)) and low leverage (column (4)). This is consistent with the capital response being indeed driven by higher bank credit. As a result of the lower capital requirements, both credit and capital investment is allocated towards firms with lower default risk and leverage.

Table 9: Firm-level heterogeneity

	(1) ΔLog(Capital)	(2) ΔLog(Capital)	(3) ΔLog(Capital)	(4) ΔLog(Capital)	(5) ΔLog(Capital)
$\text{Post}_t \times \text{Capital release}_{b,2006q4}$	7.006***	10.15***	2.225	10.64***	2.970
	(1.741)	(3.225)	(6.160)	(3.819)	(4.796)
N	41783	20202	17818	18139	19937
No. of clusters	97	95	97	95	97
Mean of depedent variable	0.0177	0.0163	0.0142	0.0172	0.0134
SD of dependent variable	0.573	0.577	0.560	0.586	0.552
Mean of capital release	0.00713	0.00713	0.00713	0.00713	0.00713
SD of capital release	0.00235	0.00235	0.00235	0.00235	0.00235
Bank FE	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Sample	All	Low default risk	High default risk	Low leverage	High leverage

Notes: * p<0.1, ** p<0.05, ***p<0.01. Mean and standard deviations are taken over the full sample period (2005 - 2009). Column (1) considers the full sample. Columns (2) and (3) consider sub-samples of firms with a 2006 (inverse) z-score below and above the median, respectively. Columns (4) and (5) consider sub-samples of firms with a 2006 leverage ratio below and above the median, respectively.

7 Robustness

As discussed in Section 4, our main identifying assumption is that, absent the Basel II transition, outcomes would have been similar both for the banks in consideration (in the bank- and loan-level analysis) and for the firms borrowing from them (in the firm-level analysis), i.e. we assume that the banks and firms with different capital releases would otherwise be on parallel trends. There are at least three threats to this assumption. We now discuss each potential threat and how we examine the robustness of our results.

First, banks with different capital releases could be systematically different in terms of the outcomes we consider. For instance, banks with a larger capital release could be banks with systematically higher lending growth, irrespective of the reduction in capital requirement. We alleviate this concern by estimating period-specific "treatment" effects prior to the transition and confirm that capital release only explains cross-sectional variation in outcomes *after* the transition. The estimated dynamic treatment effects are reported in Appendix A.1. Reassuringly, we can not reject the null hypothesis that the capital release has no significant impact on bank outcomes prior to the Basel II transition. This also indicates that anticipation effects are less of a concern in our sample, even though the Basel II transition was announced pre-2007.

Second, even if banks with different capital releases are similar prior to the transition, it could be that

they experience different credit demand shocks after the transition, which can lead to different outcomes. This is a concern, as the Basel II transition coincided with the financial crisis where both firms and banks were subject to external shocks. First, at the bank-level we find that banks with a lower initial capital ratio expand lending more in response to lower capital requirements (Table 6). This is consistent with the capital release reflecting a relaxation of capital constraints, as opposed to a positive credit demand shock. Second, we use our loan-level data to control for industry-year fixed effects. This allows us to control for potential industry-specific demand shocks in the post-treatment period. All of the loan-level results we report include such industry-year fixed effects. Third, we use information on the effects of capital release on the price of loans (i.e. the interest rate on loans). As we report in Table 4, we find a significant negative effect of capital release on the effective interest rate paid on the loan. This suggests that the effects we are capturing are associated with an increase in credit supply.

A third threat to identification is confounding credit supply shocks. There are at least two potential sources. The first source is direct exposure to the financial crisis. We note that the credit losses related to the financial crisis was limited for Norwegian banks, and in particular for the banks in our sample, reflecting their smaller size and domestic focus. Instead, the financial crisis affected Norwegian banks primarily through a tightening in liquidity; especially following the collapse of Lehman Brothers in September 2008. The Norwegian authorities, in return, implemented a series of liquidity-support measures to alleviate the liquidity crunch. If the liquidity shock and the liquidity-support measures are correlated with our measure of capital release, our estimates of the effect of capital requirement reductions could be biased.

We conduct two robustness exercises to tackle this concern. First, our results are robust to including a proxy for banks' liquidity shock exposure as a control (see Table 6, column (5)). Second, we re-estimate all of our empirical models using a post-treatment sample that stops in 2008Q3 for the bank-level results and in 2008 for the loan-level analysis due to its annual frequency. Our results are presented in Tables 10-12 in Appendix A. Our results using this shorter treatment period are consistent with our baseline results. Although we fail to reject the null hypothesis for some of the outcomes considered, all coefficients remain qualitatively unchanged and the lower significance is likely driven by the short treatment period.

Finally, even if banks with a high capital release are not directly affected by the financial crisis, they could be indirectly affected through changes in competitive pressures in the credit markets they operate in. One potential confounding factor could arise if banks with a high capital release were competing with banks that were directly affected by the financial crisis, i.e. the IRB banks. When their competitors potentially retrench their credit supply, non-IRB banks with a high capital release could expand credit to increase their market share. In order to investigate whether this is confounding our estimates, we exploit the fact that our non-IRB banks primarily operate in geographically segmented markets. For each non-IRB bank, we compute the pre-crisis market share of IRB banks in that bank's regional market and correlate it with the capital release of that bank. The results are reported in Figure 8 in Appendix A.2. If anything, our data indicates that banks with a high capital release are less exposed to competition from IRB banks, which suggests that potential effects of competitive pressures do not constitute a confounding effect on our results.

8 Conclusions and policy implications

The purpose of our empirical exercise was to investigate whether reducing capital requirements can be a tool for macroeconomic stabilization via a bank lending channel. The use of capital requirements as a stabilization tool has been an important part of the policy response during the downturn associated with the Covid-19 epidemic. Several countries, including Norway, reduced capital requirements and regulators signalled flexibility in using capital buffers. Shedding light on how capital requirements affect lending and macroeconomic variables is important for macroeconomic policy, particularly in circumstances where monetary policy space is limited.

Our empirical strategy takes advantage of Norwegian banks' transition to Basel II in 2007-2008 which led to a sizable and differential reduction in capital requirements at the bank-level and coincided with a period of economic downturn. This quasi-natural experiment allowed us to estimate the effects of reductions in capital requirements on bank lending and real economic outcomes.

Our results are broadly supportive of capital requirement reductions playing a positive stabilizing role in a downturn. We find significant and sizable effects of reducing capital requirements on the cross-section of bank lending to both households and firms. Furthermore, the relative expansion of credit at the bank- and loan-level translates into better relative real economic outcomes at the firm-level.

Moreover, our results suggest that the impact of reducing capital requirements is "double state-dependent". Specifically, the overall transmission to the real economy depends on (1) the capitalisation of the banking system and (2) on the state of the corporate sector. First, capital requirement reductions lead to more lending primarily for banks that have lower capitalisation. This is consistent with capital requirements being a binding constraint. Second, creditworthiness of the corporate sector matters. Specifically, our analysis suggests that banks respond primarily to "good" borrowers. Credit expansion and the associated increase in capital investment are driven primarily by firms with low default risk and low leverage.

This suggests that capital requirements can particularly be a potent tool if the banking system is or is expected to be constrained by capital requirements. Periods of financial sector turmoil and likely banking sector losses are therefore periods when capital requirement reductions would likely be more effective as a stabilization tool. Furthermore, the effects of capital requirement reductions can be dampened if borrowers have low creditworthiness or are highly leveraged. This result is consistent with the literature on the investment channel of monetary policy (Ottonello and Winberry, 2018), which documents that relatively less risky firms are more sensitive to monetary policy shocks. Moreover, it suggests that monetary policy accommodation and reducing capital buffers have one complementary feature - they both lead to an increase in capital investment by relatively financially healthy firms.

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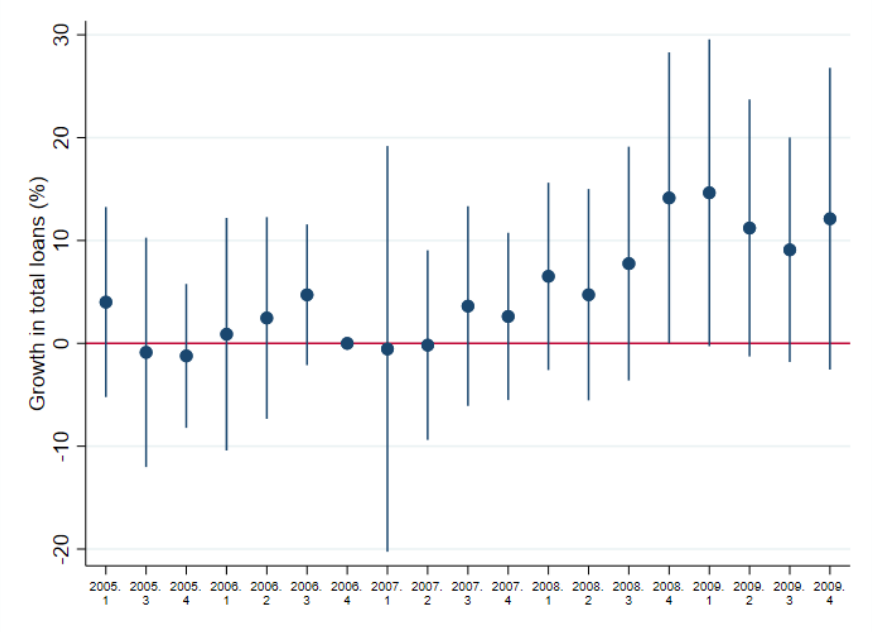
A Robustness

A.1 Parallel trends

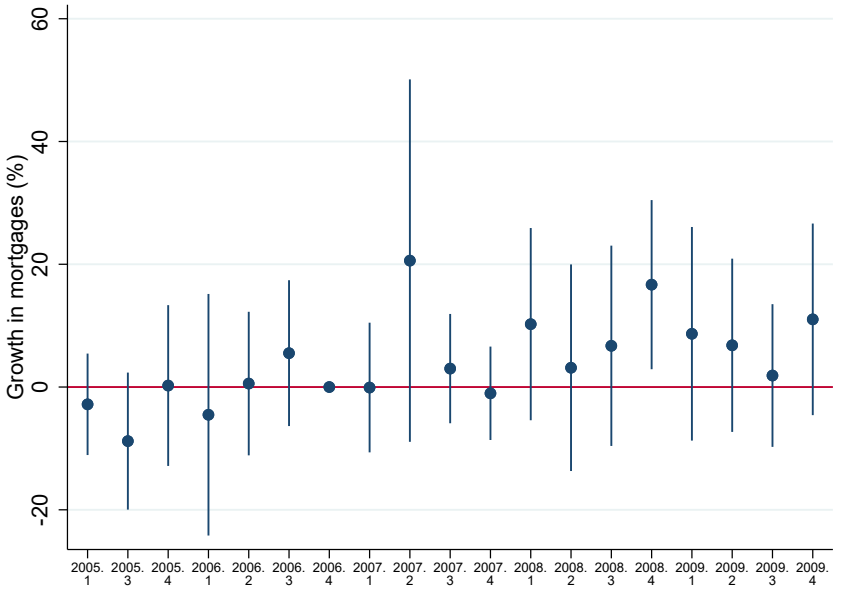
In this section, we report the coefficient estimates from estimating equation (2) at the bank-level.

Figure 3: Total loans and capital release.



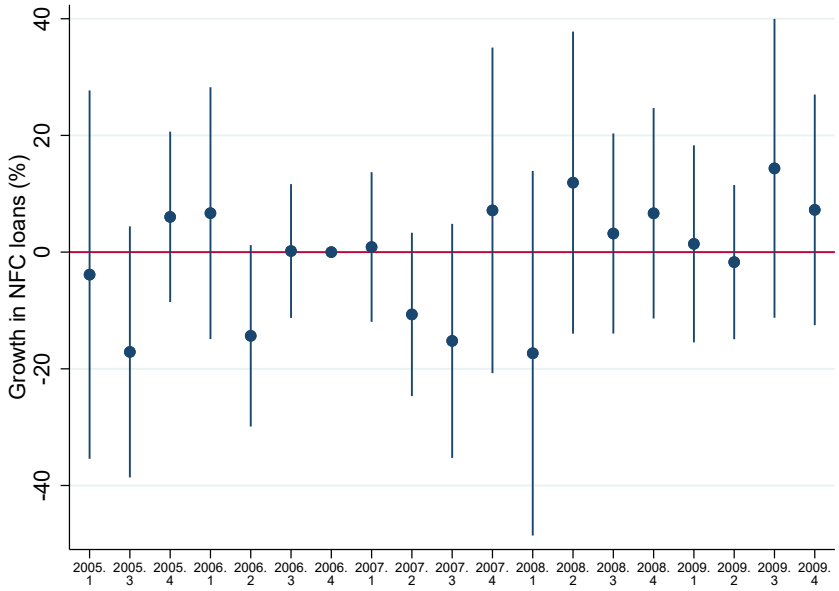
Note: This figure shows the dynamic treatment effects (γ_τ) from estimating equation (2), using the percentage change in total loans as dependent variable.

Figure 4: Mortgages and capital release



Note: This figure shows the dynamic treatment effects (γ_τ) from estimating equation (2), using the percentage change in mortgages as dependent variable.

Figure 5: NFC loans and capital lease



Note: This figure shows the dynamic treatment effects (γ_τ) from estimating equation (2), using the percentage change in NFC loans as dependent variable.

A.2 Financial crisis and the liquidity freeze

A potential threat to our identification strategy is the potential confounding effects of other shocks that affect banks' credit supply during this period. The period under our study overlaps with the intensification of the global financial crisis which may have affected credit supply through other channels.

An important channel was the significant tightening in liquidity during the crisis. Both the liquidity shock and the liquidity support measures that were announced, could affect our results, especially if there is a systematic link with the capital release. In this section, we argue that the liquidity pressures and the support measures became a significant factor only after the bankruptcy of Lehman Brothers in September 2008. We then present results which show that our results are robust to excluding this period.

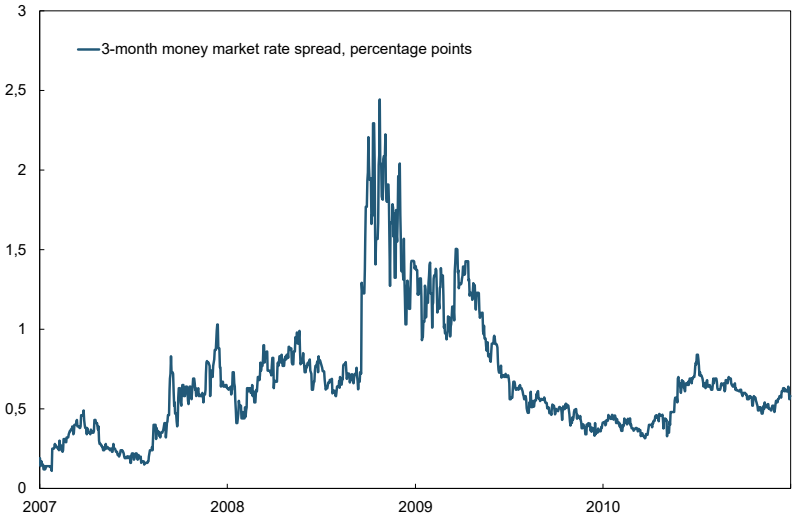
Figure 6 shows the the 3-month Norwegian money market rate spread, i.e. the difference between the rate at which banks lend to each other and the OIS rate for the same maturity, during our period of analysis. The money market spread started to increase in the second half of 2007 and remained fairly stable until it jumped significantly soon after the Lehman Brothers bankruptcy on 15 September 2008. The money market spread remained elevated through 2008Q4-2009Q1 before gradually coming down later in 2009.

Use of F-loans, which is the main lending tool used by Norges Bank to provide liquidity to the financial system, was limited to only a few of the IRB-banks in our sample before Lehman Brothers bankruptcy. F-loans taken up by non-IRB banks was small in terms of magnitude and was mainly short-term (Figure 7). Norges Bank and the Norwegian government undertook several support measures targeting the liquidity situation following the collapse of Lehman Brothers. F-loans, were increased considerably and offered in longer maturities to help strengthen banks' liquidity in Norwegian Krone.[25] This shift in liquidity needs and the provision of liquidity after Lehman Brothers is evident in Figure 7 where we show the weekly take-up of F-loans by non-IRB banks based on proprietary data on F-loans from Norges Bank. The number of banks taking F-loans increases considerably only in November 2008 when Norges Bank offered 2-year F-loans which targeted primarily the small banks. The 2-year F-loan was announced on October 12 together with an arrangement where the government provided long-term funding to banks through the exchange of mortgage-backed securities (Norwegian covered bonds) for government paper in swap-agreements.[26]

[25] Norges Bank also provided considerable US Dollar liquidity through loans and currency swap arrangements. But these measures targeted the larger and more internationally active banks which are not in our sample.

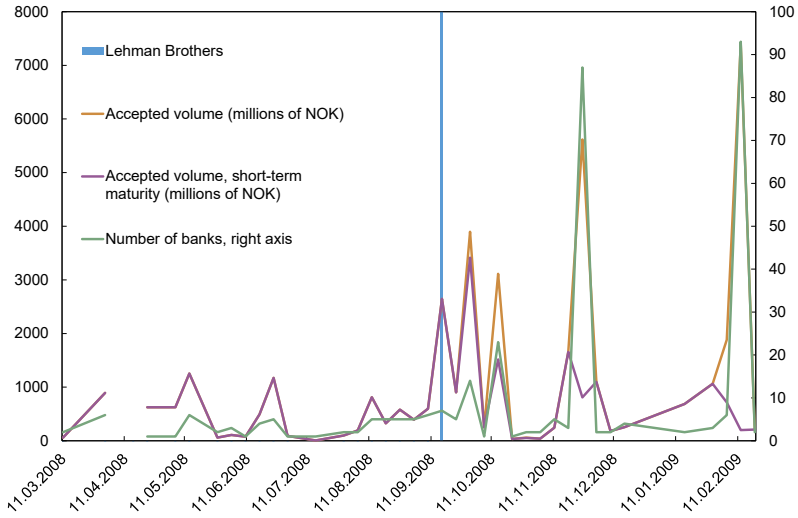
[26] The government paper could be used as collateral for loans from other banks or from Norges Bank, or be sold.

Figure 6: Developments in money market rates during the financial crisis



Source: Norges Bank.

Figure 7: Developments in F-loans to non-IRB banks during the financial crisis



Source: Norges Bank.

Having identified the Lehman Brothers bankruptcy as the key liquidity shock for our sample of banks, we re-estimate our key specifications focusing only on the first three quarters of 2008 for our results using quarterly data and 2008 for our results using annual data. Table 10 shows our results based on bank-level lending for this shorter sample. Capital release has a similarly large effect on lending based on total loans and mortgages. Our estimate for total loans is statistically significant and confirm our baseline results, while the effects on sub-components of lending are no longer significant.

Table 10: Bank-level results: Short treatment period

	(1) ΔLog(Total loans)	(2) ΔLog(Mortgages)	(3) ΔLog(NFC loans)
Post=1×Capital release	6.228**	5.683	2.469
	(2.750)	(4.177)	(5.643)
N	3,193	3,163	3,150
No. of clusters	132	132	132
Bank FE	Yes	Yes	Yes
Year-quarter FE	Yes	Yes	Yes

Notes: * p<0.1, ** p<0.05, ***p<0.01. Mean and standard deviations are taken over the full sample period (2005 - 2009). Post = 1 for 2008 and 2009, and zero otherwise. Standard errors clustered at the bank level. Sample ends in 2008q4.

We next consider the robustness of our results focusing on the interaction between capital release and bank characteristics. Table 11 shows that our baseline results hold also for this shorter sample. Capital release has a positive effect on lending, which declines with the initial level of bank capitalisation. When we control for banks' exposure to liquidity shocks (column 5), we find that capital release is still associated with higher lending growth but the interaction of capital release with liquidity shock exposure is no longer significant.

Table 11: Bank-level outcomes, heterogeneity: Short treatment period.

	(1) Δ Log(Total loans)	(2) Δ Log(Total loans)	(3) Δ Log(Total loans)	(4) Δ Log(Total loans)	(5) Δ Log(Total loans)
Post=1 × Capital release	11.86***	-31.22	6.965	8.350	9.031**
	(3.473)	(20.45)	(7.257)	(5.791)	(3.760)
Post=1 × Capital release × Equity ratio, 2007	-80.98**				
	(33.85)				
Post=1 × Capital release × Log(total assets), 2007		2.359*			
		(1.372)			
Post=1 × Capital release × RoA, 2007			-74.69		
			(586.1)		
Post=1 × Capital release × Writeoffs / Total assets, 2007				769.2	
				(677.0)	
Post=1 × Capital release × Interbank borrowing / Total assets, 2007					6.448
					(5.603)
N	3,177	3,177	3,177	2,993	2,693
No. of clusters	130	130	130	121	110
Bank FE	Yes	Yes	Yes	Yes	Yes
Year-quarter FE	Yes	Yes	Yes	Yes	Yes

Notes: ∗ ∗ ∗ indicates p<0.01, ∗∗ indicates p<0.05 and ∗ indicates p<0.1. Standard errors are clustered at the bank-level. This table shows the results from estimating equation (3) using the loan-level symmetric credit growth, imputed interest rate and dummy for new loan as dependent variable, respectively. Standard errors are clustered at the bank-level. Sample ends in 2008q4.

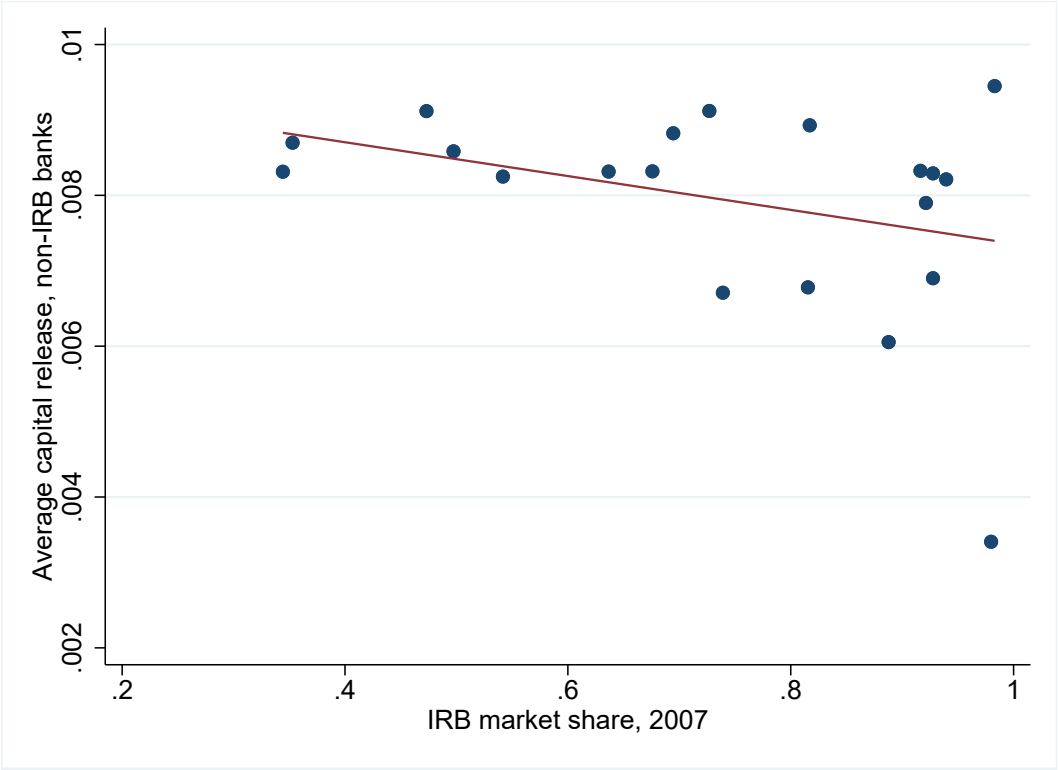
Finally we report our short-sample results for loan-level outcomes. Capital release has a positive effect on loan-level lending, but its coefficient is no longer significant. This likely reflects the higher annual variation in lending growth relative to the average over two years in the baseline sample. Our results for the effect of capital release on average effective interest rate and the probability of new lending relationships (extensive margin of lending) remain intact and significant when we use the shorter treatment period.

Table 12: Loan-level outcomes: Short treatment period.

	(1) Credit growth	(2) Interest rate	(3) New relationship = 1
Post=1×Capital release	5.050	-0.364**	29.38***
	(3.377)	(0.173)	(5.246)
N	50,593	66,161	66,161
No. of clusters	96	98	98
Bank FE	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Firm industry x Year FE	Yes	Yes	Yes

Notes: ∗ ∗ ∗ indicates p<0.01, ∗∗ indicates p<0.05 and ∗ indicates p<0.1. Standard errors are clustered at the bank-level. This table shows the results from estimating equation (3) using the loan-level symmetric credit growth, imputed interest rate and dummy for new loan as dependent variable, respectively. Sample ends in 2008.

Figure 8: Pre-crisis IRB share and capital release



Notes: This figure shows a binned scatter-plot of the pre-crisis market share of IRB banks for all non-IRB banks and the associated non-IRB banks' capital release. Each dot represent the median in a bin of 7 banks.