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Capital Requirements, Credit Supply, and Real Effects on Firms

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Capital Requirements, Credit Supply, and Real Effects on Firms

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Abstract

In this paper, we estimate the impact of capital requirement (CR) changes on corporate lending and real economic outcomes using granular firm-bank data from Hungary. Leveraging detailed loan-level and firm-balance sheet information, we find significant credit supply reductions and interest rate increases following tighter CR, with multibank firms showing notably stronger immediate reactions. While firms partially offset these impacts by forming new banking relationships, aggregate firm-level effects remain substantial: a 1 percentage point increase in firm-level CR reduces corporate credit volume by 2.5–6.0% and elevates interest rates by 2.0–4.8 basis points. Real activity deteriorates significantly, with investment declining by 1.5%, sales by 1%, and employment marginally. Smaller firms and those reliant on domestic banks are disproportionately affected, whereas firms borrowing from foreign banks applying IRB methods experience milder disruptions. Our findings highlight critical trade-offs in bank capital regulation, firms' ability to adapt to new circumstances and underscore the differential vulnerability of smaller firms to credit supply shocks.

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1.1. Motivation and background

Capital requirements (CR) are one of the main tools of supervisory authorities and central banks to increase the resiliency of banks and the financial system generally. CR frameworks have changed several times since the publication of Basel III in 2010, the recommendation of the BCBS[1]. The adaptation of these modifications in the EU, e.g., introducing an output floor and input floor for the internal ratings-based calculations, is estimated to increase CRs by 7.8% (EBA, 2023). However, their impacts on lending and the real economy are still debated. While some argue that banks can adjust their liabilities to comply with higher capital requirements (Admati & Hellwig, 2014), there is growing evidence that asset-side adjustments are widespread at financial institutions (Behn et al., 2016; Gropp et al., 2019), which directly imply decreased lending. The question is becoming even more relevant as "leaning against the wind", or cyclically limiting lending is a dedicated goal for some macroprudential policies (Aiyar et al., 2014). Furthermore, several supporting factors are implemented in the EU, such as the SME and infrastructure supporting factors, which decrease CRs for targeted exposures to direct lending to certain areas and achieve policy goals. There is no consensus on whether these supporting factors can structurally promote lending to these targeted areas (EBA, 2016).

In this paper, we estimate how relative changes in a firm's capital requirement at a bank impact the institution's credit supply toward the firm and what the general equilibrium effects are at the firm level, including real economic consequences. Several factors can impact corporate lending, including a firm's credit demand and risk, as well as bank-specific shocks unrelated to capital requirements, such as business strategy, risk appetite, and the market environment. This makes empirical identification of the capital requirement channel difficult, as these factors can bias the sensitivity estimates on lending if they are correlated with capital requirements. We use sharp identification by observing firms with multiple lenders and heterogeneous capital requirements, a standard solution in the bank credit supply literature to address this limitation (Khwaja & Mian, 2008).

To estimate the impact of capital requirements on bank lending, we exploit the intrinsic heterogeneity of capital requirements across banks to a particular firm to assess this question, similar to Fraisse et al. (2020). By saturating our model with fixed effects on time and bank, we can eliminate the potential confounders of market-wide distress and bank-specific attributes such as risk appetite. Bank-time fixed effects can control for shocks hitting banks during our

[1] Basel Committee on Banking Supervision

observation period, such as funding shocks, a documented channel in the literature that can severely hurt lending volume. Finally, introducing firm-time fixed effects into our modeling allows us to control for firm-specific credit demand and risk. This is important, as credit supply and demand can be highly correlated, and we need to untangle the effects. We use panel regressions with multiple fixed effects specifications and a complete loan-level dataset covering all corporates from the Central Bank of Hungary to robustly address the relationship between capital requirement and lending. Our data enables us to estimate volume effects on lending and interest rate impacts, which is rare in the literature. Using granular balance sheet data, we also estimate firm-level real impacts of CR changes on investment, revenue, and employment.

Analyzing the impact of CRs in Hungary offers an interesting case study for multiple reasons. Firstly, in many instances, advanced economies have been analyzed in the literature using loan-level data, while evidence on small open economies is virtually non-existent. Sensitivity to CR shocks could be different in larger and more advanced economies since large banking groups in those countries have easier access to funds; hence, raising equity is less expensive for them than for smaller banks. Domestic banks need to raise capital directly to improve their capital ratios, which is more costly than internal capital transfers, and it is also a viable option for subsidiaries of banking groups. In the Hungarian banking system, subsidiaries of large foreign banking groups and domestic banks have substantial market shares, providing a unique opportunity to assess the heterogeneous behavior of subsidiaries. Secondly, the Central Bank of Hungary has loan-level data consisting of multiple volume and interest rate information for each loan contract and collateral values, ideal for a detailed empirical analysis. Our data consists of all banks' corporate loans, hence covering the entire corporate credit market. Additionally, we can also observe loan applications by firms rejected by banks, a unique feature of this credit registry. Based on our data's coverage, length and size, it is more exhaustive than the data used by Fraisse et al. (2020).

We proceed in four steps. Firstly, we estimate the CR impact on the firm-bank pair level of lending. We find that a 1 percentage point increase in capital requirements leads to an 8.3 – 16.8 percent decrease in lending volume. Multibank firms' relations to their banks are more sensitive to CR changes (13.7–16.8 percent), while the volume sensitivity of all firms is closer to 10 percent, which is the reason for the broader range of our results. Regarding our results on the price effects, we see that a 1 percentage point increase in capital requirements leads to higher interest rates by 4.6 – 10.9 basis points. This is a substantial effect as the interquartile range between the 25^{th} and the 75^{th} percentile of firm-bank pair CR changes in a year is 0.6 percentage points.

Secondly, we examine the firm-level credit effects to assess the extent to which firms can substitute across their lenders. We show that these effects persist on the firm level but are lower in magnitude. Our raw estimates imply that a 1 percentage point increase in capital requirement at the firm level leads to a 2.5 – 3 percent reduction in lending volume. If we follow the credit demand correction procedure by Jimenez et al. (2021), the range of our corrected estimates is 4.8 – 6.0 percent. Similarly, the uncorrected estimated interest rate impact range on the firm level is 1.1 – 2.0 basis points, while the demand corrected range is 2.0 – 4.8 basis points. While demand-corrected estimates are likely closer to the general equilibrium effects of CRs since they consider the unobserved covariance between credit supply and demand shocks, there is some uncertainty around the firm-level impacts. However, our results imply that the firms can dampen the CR effect, e.g., through applications to new banks, a channel we document. Using a loan application proxy and the actual number of new banking relations of firms, we show that CR shocks significantly affect firms' loan application activity, as increased (decreased) CRs imply more (less) applications and new banking relations. The connection between new banking relations and capital requirements has not been assessed previously in the literature.

Thirdly, we analyze the firm-level impacts on the firms' real economic activity. Using the firm's balance sheet data, we evaluate the effect of firm-level CR changes on total assets, revenue, investments, and employment. Our results show significant CR effects. A 1 percentage point increase in firm-level CR translates to a 0.5 percent decrease in assets and a 1 percent drop in revenues. Investment impacts are more substantial. We document a 1.5 percent decrease in fixed assets. There are significant but lower impacts on employment as well. We cannot perform the demand correction for real impacts, which could potentially increase our estimates. To assess the potentially heterogeneous impacts of different firm sizes on lending and real activity, we estimate CR – firm size interaction terms across four firm quartiles using the first observed sales and employment metrics as size measures. While banks do not seem to be selective about CR changes, and lending impacts are not more significant for smaller firms, the disrupting credit shocks impact smaller firms more substantially, as their investments decrease by 2.5 percent after a 1 percentage point change in firm-level CR increase.

Finally, we address whether domestic banks using entirely SA approaches in Pillar I and subsidiary banks using IRB approaches behave differently. We find that firm-bank relationships with domestic banks are more sensitive to CR shocks, both in terms of volume and interest rate. This difference persists at the firm level, as firms with relation to foreign banks' credit volume and interest rates are less impacted than firms without foreign bank relations. While this aligns with finance theory, as subsidiary banks can obtain equity financing through internal capital markets more easily than domestic banks, IRB capital calculations can also cause this difference. Nevertheless, our results suggest that subsidiary banks of large banking groups can moderate CR shocks in the economy, either through their funding or modeling capabilities.

We perform several robustness checks to tackle concerns about data problems and modeling choices. We estimate a plethora of model specifications; we use multiple outcome variables to increase the validity of our results. We perform our core modeling using winsorized data as well to make sure our results are not driven by outliers. Additionally, as a novelty in the literature, we combine sharp identification with collateral information. This is important as increasing pledged collateral values can mitigate a loan contract's riskiness, which could bias our CR impact estimates. However, the inclusion of collateral value into our model specifications does not change our coefficients. We estimate impacts on different subsamples, across different years and by leaving out different banks of the sample to assess robustness. The estimates are stable across time and bank samples. Banks' manipulation of the regulatory models to obtain more favorable capital requirements is unlikely to be the case for Hungary, as portfolios covered by IRB models are unchanged during the period.

We propose a novel methodology to test whether our estimates are driven by the bank's risk perception heterogeneity. Using the average leads and lags of other banks' CRs to a firm, we can control for delays in risk monitoring among banks, a likely channel that could cause differences in banks' opinions in a given period over a given firm's risk. Our results show that even after controlling for potential delays in observing risk shocks on firms by banks, the effect of CRs on lending volume and interest rates remains significant and substantial. Furthermore, the proposed methodology can be used generally to disentangle the effects of capital requirements and risk perception when credit registry data is available.

We conduct a placebo test on the relationship between credit volume and capital requirements. We estimate first difference panel models on exposure at default, capital requirements, and lags. In the placebo model, we estimate whether the next period's capital requirement affects exposure at default in the current period. We use the next year's CR as another test for risk perception distortion, as the bank's soft information on firm fundamentals could be proxied by the value of its next year's CR to some extent. Hence, if we found strong impacts from future capital requirements, that would imply that our previous results are distorted by the bank's risk perception. Our results indicate that while the coefficient of the lead CR is significant in some specifications, the absolute value of the coefficient is constantly low; more than 92 percent of the CR impact on volume was unrelated to the placebo term. Again, this implies that heterogenous risk beliefs are not the main driver of our results.

The primary objective of CRs is to promote prudent financial institutions and, hence, a stable financial system, a public good. There is some empirical evidence that bank regulation can sustain lending during crises. Banks with weaker core capital positions restricted the loan supply more strongly in these periods (Gambacorta & Marques-Ibanez, 2011). Similarly, banks with lower liquidity risks cut their lending less during the 2008 crisis (Ivashina & Scharfstein, 2010). We do not evaluate the impacts of capital requirements on financial stability or perform a welfare analysis to find the optimal level of capital requirements. We focus on estimating the impacts of CRs on lending and the real economy, not calibrating their optimal level.

Our work contributes to the literature on capital requirements and bank lending. It is established by this literature that contrary to the Miller-Modigliani views, banks ration credit when they face higher capital requirements, at least in the short run (Aiyar et al., 2014; De Jonghe et al., 2020; Favara et al., 2021; Gropp et al., 2019). Previous studies used different settings to identify the effect, such as the 2011 EBA capital exercise (Gropp et al., 2019), the buffer for global systemically important banks in the US (Favara et al., 2021), the time-varying capital requirements in the UK (Aiyar et al., 2014). Fang et al. (2022) confirmed that short-run credit rationing effects hold in Peru, an emerging market. Credit growth rate sensitivity estimates on capital requirements are between 2 - 9 percentage points (Busies et al., 2024). Our estimates are in the upper part of this range, and in some cases, they are larger. We show that estimated partial and general equilibrium effects can vary substantially as firms adapt to their new credit environment.

Apart from the quantity effects of capital requirements on lending, we add to the price effect estimates previously obtained in the literature. Basten (2020) showed that in Switzerland, after introducing a countercyclical buffer of 1 percentage point, there was no significant credit spread increase on aggregate, but more heavily impacted banks raised interest rates by 8 basis points. Benetton et al. (2021) found an impact of similar magnitude, 10-16 basis points impact per 1 percentage point change in the UK mortgage market. King (2010) estimated an 11-15 basis points impact on interest rates. A novelty of our study is that we estimate significant interest rate impacts for corporates in a sharp identification setup, which are substantial effects according to our results and are in line with previous estimates in the retail segment.

We also contribute to the literature on capital requirements impacts on the real economy and credit shocks in general (Behn et al., 2016; Favara et al., 2021; Fraisse et al., 2020; Gropp et al., 2019; Jiménez et al., 2020). Recent studies have shown that credit supply shocks induced by regulatory actions such as capital exercises affect firms' real activity. Gropp et al. (2019) estimated asset, revenue, and investment growth rates 4-6 percentage points lower for firms with strong relationships with banks in a capital exercise. Direct estimates on real activities' sensitivity to firm-level CRs, Fraisse et al. (2020) found impacts in the 0.8 - 2.7 percent range per percentage point, with investments being the most sensitive and employment figures the least. Our estimates are in a similar range and support these previous results.

Furthermore, we contribute to the literature on subsidiaries and the impact of foreign-owned banks on the credit market. Previous empirical results point towards foreign banks being less equity-constrained and spurring competition. Subsidiary banks often lend with softer capital constraints using internal capital markets that can support the credit supply (De Haas & Van Lelyveld, 2010). In the context of Central Eastern Europe, Temesvary & Banai (2017) showed that subsidiary banks behave differently and parent group traits have a significant role in their subsidiaries' lending activity. Additionally, banking systems with greater foreign bank entry tend to be more competitive (Claessens & Laeven, 2004). Banks using IRB methodologies, however, have also been identified as a mitigating factor on capital regulation's market impact (Gopalakrishnan et al., 2021). We show that even a parent bank's risk and capital modeling capabilities can be a competitive advantage for subsidiaries and dampen borrower firms' credit disruptions.

1.2. Empirical strategy and data

1.2.1. Data

We use the Credit Registry of the Central Bank of Hungary (HITREG) to obtain loan-specific capital requirements, exposure, interest rates, and all other relevant information on corporate borrowing in the period between 2019Q4 and 2024Q3. We aggregate this information weighted by EAD for each firm-bank pair in each quarter. We limited our sample to the 9 largest banking groups in the country, which have sizeable corporate portfolios, and to firms that are not solo entrepreneurs and are subject to corporate tax. The constructed data includes all active firm-bank pairs, which are existing lender-borrower relationships.

For the firm-level results, we combine the credit data with the balance sheet information of the corresponding corporations. Firm-level financial variables were found in 71 percent of all loans. For each year, we use the firm's end-of-the-year balance sheet data on fixed assets, sales, and the number of employees. Note that the frequency of our firm-level balance sheet data is yearly compared to the quarterly credit.

We are interested in the effect of capital requirement on various borrower measures. Pillar I is the most transparent part of the capital requirements framework, where both banks and supervisors follow existing rules, and they can both replicate each other's results. Additionally, PI capital requirements depend on the loan contracts and counterparties and not on portfolio or bank-level risks such as credit concentration, corporate governance, business model, etc. These features of PI capital requirements make it a perfect candidate for our analysis since capital allocation rules are not necessary to define it on the bank-firm level, and banks can use it for internal processes and reporting without modifications.

Our variables of interest in bank lending are the EAD and interest rates. For robustness, we also measure the impacts on interest rates of non-subsidized loans, a subset of all loans due to the high share of different subsidy schemes in Hungary and outstanding loan amounts to understand credit lines better. On firm fundamentals, we estimate impacts on sales, fixed assets, and employment. We aggregate the loan level Pillar I reported capital requirements by taking their exposure weighted mean, similarly to interest rates both for firm-bank pair and firm level.

Table 1: Data descriptives

variable	n	Mean	SD	Min	q25	Median	q75	Max
Exposure at default (mln HUF)	1261701	20923.7	3112205.1	0.0	3.0	10.3	57.0	2260490514
Exposure at default (win, mln HUF)	1261701	296.4	1324.0	0.0	3.0	10.3	57.0	13798
Outstanding loan amount (mln HUF)	1259415	929.3	24867.1	0.0	2.5	9.4	53.8	7098840
Outstanding loan amount (winsor, mln HUF)	1259415	241.5	1000.5	0.0	2.5	9.4	53.8	10324
log EAD	1261701	16.431	2.56	0.693	14.932	16.157	17.873	35.354
log EAD_winsor	1261701	16.413	2.5	0.693	14.932	16.157	17.873	23.348
CR	1261701	5.277	3.755	0	2.901	6	6.647	117.955
CR_winsor	1261701	5.342	2.918	0.224	3.333	6	7.224	17.778
Interest rate winsor	1161740	7.931	5.416	0	3.445	7	11.27	25.5
Interest rate – Not subsidized	851959	8.793	5.502	-2.57	4.86	7.77	12.123	54.538
Interest rate – Not subsidized _winsor	851959	8.766	5.419	0	4.86	7.77	12.123	26.25
log Collateral value	1261701	3.858	6.744	0	0	0	0	27.159
IRB ratio	1261701	0.171	0.375	0	0	0	0	1.037

The table shows the descriptive statistics of the loan-level data.

Overall, our data on firm-bank pair linkages consists of 1.16 million firm-bank-period triads that we can use in our model estimations, and we have 410 thousand observations for firms borrowing from multiple banks simultaneously. Our data on the firm level consists of 267 thousand observations on firm-period pairs.

1.2.2. Empirical strategy

Our identification is based on the minimum capital requirements in the current Basel framework, where pillar I capital requirements are based either on the Standard (SA) approach or the Internal Rating Based approach (IRB). The SA approach calculates capital using predefined values based on borrower and loan characteristics, while the IRB approach is based on banks' own models. Capital requirements calculated by the IRB approach are inherently heterogeneous across banks. Banks calculating different capital requirements for other firms is another layer of variation in our variable of interest. We measure the firm-bank level capital requirements as the Pillar I risk weights reported by banks multiplied by the regulatory constant of 8 percent.2

Similarly to Fraisse et al. (2020), we use panel regressions with similar multiple fixed effects specifications. We assess capital requirement's ($K_{t,f,b}$) effect on lending volume and interest rates ($Y_{t,f,b}$), denoted by β in Eq. (1). We use the one-year lag of capital requirement to estimate this impact.

$$Y_{t,f,b} = \alpha + \beta \cdot K_{(t-1),f,b} + \gamma_{f,(t)} + \delta_{b,t} + \varepsilon_{t,f,b} \quad (1)$$

In our most saturated model, we include bank-time fixed effects ($\delta_{b,t}$) to control for bank specific funding shocks and firm-time fixed effects ($\gamma_{f,(t)}$) to filter out changes in firm fundamentals over time. The last term, $\varepsilon_{t,f,b}$ is the error term for the specific firm (f) and bank (b) pair at time t. We double-cluster the errors for both banks and firms.

We also estimate models without bank-time and firm-time fixed effects and consecutively introduce these terms. Note that firm-time fixed effects models can only be identified for firms with multiple observations in the same period, i.e., multiple banking relationships. These might significantly differ from other firms, so we also estimate a model with bank-time fixed effects on the sample of multibank firms.

For the firm-level results, we estimate changes in the firm-level capital requirements' impact on the firm's borrowings and consequently on the firm's balance sheet and real economy outcomes. Similarly to the previous setup, we use one-year lags of the average capital requirements of the firm. In our most saturated model, we include firm fixed effects (γ_f) to control for constant firm fundamentals, sector-time fixed effects ($\theta_{s,t}$) to control for sector-specific shocks and bank-time fixed effects ($\delta_{b,t}$) for bank funding shocks, similarly to before. We cluster the errors ($\varepsilon_{t,f}$) at the firm-level.

$$Y_{t,f} = \alpha + \beta \cdot K_{(t-1),f} + \gamma_f + \theta_{s,t} + \sum \delta_{b,t} + \varepsilon_{t,f} \quad (2)$$

Note that firm-time fixed effects cannot be specified in this setup since we have one observation per firm in each period. This is why we control for shocks hitting the sector of the firm in each period. Additionally, we calculate the estimator ($\bar{\beta}$) proposed by Jiménez et al. (2020) to address potential bias by heterogeneous credit demand of firms that we cannot directly control for using the firm-level data, similar to Behn et al. (2016). This estimator corrects the firm-level coefficient (beta bar sub n o cap F cap E) based on the difference between the loan-level coefficient of the model with (β_{FE}) and without (β_{noFE}) the firm FEs. We also calculate these corrected estimates for firm-level credit volume and interest rate impacts.

$$\bar{\beta} = \bar{\beta}_{noFE} - (\beta_{noFE} - \beta_{FE}) \cdot \frac{var(\delta_i)}{var(\bar{\delta_i})} \quad (3)$$

We can use quarterly data for credit market impacts (volume and interest rate), while our data has a yearly frequency for balance sheet and real impacts.

1.3. Results

1.3.1. Firm-bank pair results

Table 2 presents the estimates on the impact of capital requirements on bank-firm-level credit volume with various model specifications. Estimates in this setup correspond to effects on the intensive margin since we use the actual CRs, which are firm-bank-period specific and are observed only for existing firm-bank relationships. As a result, we use the most granular information at our disposal, with the largest number of observations in this setup. The dependent variable is log(1 + exposure at default at the bank), while the variable of interest is the one-year lagged exposure weighted average of capital requirements for the firm at the particular bank.

[2] This choice is motivated by data availability. Furthermore, pillar I risk weights are observed by the banks and thus their internal capital allocations are likely to be based on these.

We introduce many targeted fixed effects (FEs) to control for various other effects step-by-step. In Model (1), we include quarterly FEs to capture macroeconomic shocks, firm FEs to control for firm-specific effects, and bank FEs to capture possible differences in credit policies and other bank-specific effects. In Model (2), we introduce bank-time FEs to control for bank-specific funding shocks, which have been pointed out as important drivers of credit growth by previous research (Peek & Rosengren, 2000; Stein, 2012). The sample shrinks to multibank firms since we include firm-time FEs in Model (4), which is only identified to firms with many existing banking relations in a given period. We estimate Model (3) for that subsample with the same specification as in Model (2). Finally, we estimate Model (4) with the mentioned firm-time FEs to control for firm-specific shocks and other demand-side effects. Again, we can only estimate it for firms with multiple lenders simultaneously due to the identification issue. In our most saturated Model (4), identification comes from the same firm borrowing from multiple banks, but different banks might obtain different capital requirements for the same firm, which is a powerful identification since one firm has one level of overall risk and demand. We similarly introduce models for outstanding loan amounts across columns (5) – (8).

Our estimates are consistently significant both statistically and economically across models. A percentage points increase in capital requirements for a given firm at a given bank decreases credit volume in the 8-17 percent range. The results show that multibank firms are more sensitive to changes in CRs, as the same specifications give largely different outcomes in Model (2) and (3) for the whole sample and the subset of multibank firms. Results for outstanding loan amounts are almost identical to exposure at default, suggesting that the credit volume impact is robust across metrics.

Table 2: Firm-bank pair estimates on credit volume

	log EAD				log outstanding principal			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
lag_4q_CR	-0.087**	-0.092**	-0.138**	-0.168***	-0.083**	-0.088**	-0.137**	-0.166***
	(0.037)	(0.038)	(0.046)	(0.035)	(0.035)	(0.036)	(0.047)	(0.036)
Time FE	Yes	-	-	-	Yes	-	-	-
Bank FE	Yes	-	-	-	Yes	-	-	-
Firm FE	Yes	Yes	Yes	-	Yes	Yes	Yes	-
Bank x Time FE	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Firm x Time FE	No	No	No	Yes	No	No	No	Yes
Cluster	Bank-Firm	Bank-Firm	Bank-Firm	Bank-Firm	Bank-Firm	Bank-Firm	Bank-Firm	Bank-Firm
Sample	Full	Full	Multibanks	Multibanks	Full	Full	Multibanks	Multibanks
Observations	1,383,542	1,383,542	495,204	495,204	1,288,721	1,288,721	454,740	454,740
R^2	0.740	0.747	0.594	0.898	0.734	0.738	0.601	0.894

The table shows the coefficient estimates of capital requirements on lending volume in Eq. 1. The dependent variable is the logarithm of exposure at default and outstanding loan amount, and the variable of interest in the 4 estimated panel regressions is one year lagged capital requirements. Standard errors are shown in parentheses below the estimated coefficient, asterisks indicate statistical significance. Estimated models progressively include fixed effects (FEs) across Model (1) to (4) and (5) to (8). The sample in Model (3) - (4) and (7)-(8) is limited to firms with multiple bank lenders to identify firm-period FEs. Error terms are double clustered at the bank and firm levels in all cases.

Now, we turn to interest rate effects. Table 3 shows estimates on the impact of capital requirements on the price of credit on bank-firm level, with many model specifications. The dependent variable in this case is the average interest rate at a bank for a firm, similarly to previously, we use one year lagged capital requirements for the firm at the bank. We saturate the models with FEs in a similar manner. Since identifying the CR effect with firm-time FEs is only possible for multibank firms, we limit our sample to those in Models (3) and (4). In the right-hand part of the table, we show the results of an alternative approach where only those loans are considered in the analysis which were not included in any subsidy scheme funded by the government or central bank. This is a robustness test to assess whether non-market based interest rates drive our results. This sample is reduced to observations with existing non-subsidized loans. In Model (4) and (8) we estimate a fully saturated specification with firm-time FEs for multibanks.

The estimated coefficients are consistently positive and of the same magnitude. Based on these estimates, a percentage points increase in capital requirements for a given firm at a given bank increases the interest rate by 3-11 basis points, slightly lower on the non-subsidized sample. Note that this increase is estimated for a firm's whole stock of borrowings from a bank, not only for newly originated loans. The less saturated models' coefficients are less or not significant, but this can be attributed to our conservative standard error estimation approach since we use double clustering at the firm and bank level. If we cluster only at the firm level, the coefficient in Model (2) would be significant at a 1 percent level. Similarly to volume estimates, the effects are larger and highly significant on the multibank sample for both interest rate metrics. The difference between Model (3) - (4) and (7) – (8) is consistently around 3 basis points, suggesting that including firm FEs to control for credit demand and other firm-specific shocks increases the estimated CR impact, if only marginally.

Table 3: Firm-bank pair estimates on interest rates

	Interest rate				Not supported Interest rate			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
lag_4q_CR	0.059^{*}	0.046	0.080^{**}	0.109^{***}	0.047	0.031	0.069^{**}	0.102^{***}
	(0.028)	(0.028)	(0.030)	(0.019)	(0.034)	(0.030)	(0.030)	(0.016)
Time FE	Yes	-	-	-	Yes	-	-	-
Bank FE	Yes	-	-	-	Yes	-	-	-
Firm FE	Yes	Yes	Yes	-	Yes	Yes	Yes	-
Bank x Time FE	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Firm x Time FE	No	No	No	Yes	No	No	No	Yes
Cluster	Bank-Firm	Bank-Firm	Bank-Firm	Bank-Firm	Bank-Firm	Bank-Firm	Bank-Firm	Bank-Firm
Sample	Full	Full	Multib.	Multib.	Non supp.	Non supp.	NS & Mult	NS & Mult
Observations	1,274,586	1,274,586	469,829	469,829	934,876	934,876	358,946	358,946
R^2	0.646	0.654	0.504	0.897	0.641	0.662	0.567	0.916
Note:								$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

The table shows the coefficient estimates of capital requirements on lending rates in Eq. 1. The dependent variable is the interest rate of loans at the bank for the given firm, and the variable of interest in the 4 estimated panel regressions is one year lagged capital requirements. Standard errors are shown in parentheses below the estimated coefficient, asterisks indicate statistical significance. Estimated models progressively include fixed effects (FEs). Model (1) to (4) uses regular average interest rate as the dependent variable, Model (5) – (8) conditional average of the not subsidized *loans. The sample in Model (3)-(4) and (7)-(8) is limited to firms with multiple bank lenders to identify firm-period FEs, in Model (5) – (8) sample consists of linkages with not* subsidized *loans. Error terms are double clustered at the bank and firm levels in all cases.*

1.3.2. Firm-level results

We have just shown that an increase in firm-bank-specific capital requirements increases interest rates and decreases lending volume for the firm-bank pair. We now turn to the firm-level results on credit volume, interest rate, and real economic outcomes and evaluate whether firms can substitute their source of credit. To address this question, we aggregate our firm-bank pair data to the firm level in each period and estimate multiple model specifications of Eq. (2). Since we have firm-level data, we cannot control for firm-time specific shocks, such as deterioration of firm fundamentals. To mitigate this issue, we include sector-time specific FEs in our mode specifications, which can capture sector-level supply or demand shocks that might impact firm fundamentals, similarly to Fraisse et al. (2020), and also calculate demand corrected estimators. Additionally, to address the impacts of bank funding shocks on the firm's lenders, we include bank-time FE for each of the firm's existing borrower relations. Due to the aggregation, our sample size is reduced, and we cluster our results at the firm level.

Table 4 shows the sensitivity estimates of aggregated firm credit to changes in the exposure-weighted average capital requirement of the firm. We document the impact on total exposure at default and total outstanding loan amount as well. The difference between the two is that the latter does not include the expected credit conversion of undrawn amounts of credit lines. Our estimated models are saturated by time FEs across all specifications, and we include sector-time and bank-time FEs consecutively. Our estimates are in the range of 1.8 – 3% and are consistently significant, both statistically and economically. We also apply the demand corrected estimators by Jiménez et al. (2020) to account for heterogenous credit demand by the firms, described in the Methodology section. We use coefficient estimates from Table 2, columns (3) and (7) for non-FE coefficients, and use columns (4) and (8) for FE loan level estimates in the procedure since they are both based on the same sample of multibank firms, the only sample where this difference can be observed. The corrected estimates are reported at the bottom of the table. They tend to be significantly larger in magnitude, the impact estimates are in the range of 4.8 – 6.0 percent, implying a smaller crowding out effect than our direct estimates.

Table 4: Firm-level estimates on credit volume

	log Total EAD			log Total outstanding amount		
	(1)	(2)	(3)	(4)	(5)	(6)
lag_4q_CR	-0.030***	-0.030***	-0.025***	-0.027***	-0.027***	-0.018***
	(0.002)	(0.002)	(0.001)	(0.003)	(0.003)	(0.003)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Sector x Time	No	Yes	Yes	No	Yes	Yes
Bank x Time FE	No	No	Yes	No	No	Yes
Sample	Full	Full	Full	Full	Full	Full
Observations	284,614	284,614	284,614	284,614	284,614	284,614
R^2	0.874	0.875	0.886	0.817	0.818	0.825
Demand corr.	-0.060	-0.060	-0.055	-0.055	-0.055	-0.048
Note:						*p<0.1; **p<0.05; ***p<0.01

The table shows the coefficient estimates of capital requirements (CR) on lending volume at the firm level. The dependent variable is the log of the sum of all lending volume for the given firm across banks, and the variable of interest is one-year lagged capital requirements. Standard errors are shown in parentheses below the estimated coefficient, asterisks indicate statistical significance. Estimated models progressively include fixed effects (FEs). Model (1) - (3) use exposure at the default as a dependent variable, and Model (4) – (6) use the outstanding loan amount. Error terms are clustered at the firm level in all cases. Demand corrected estimates calculated using Eq. (3) are presented at the bottom.

Next, we turn to the interest rate effect of CR changes at the firm level. We examine this effect similarly to the firm-level volume effect, the results are shown in Table 5. Our two dependent variables are firm-level exposure weighted average interest rate for all and for non-subsidized loans, similar to firm-bank pair analysis. While the results are statistically significant in some cases, the estimated interest rate impact at the firm level is relatively small, around or less than 2 basis points in all cases. The demand corrected estimates shown at the bottom of the table are in the broader range of 2.0 to 4.8 basis points, suggesting a more persistent interest rate impact at the firm level. Overall, the firm-level impacts of CR changes tend to be lower than our bank-firm-level estimates. The demand correction procedure shifts our direct firm-level impact estimates upwards, but they are persistently lower than the bank-firm level impacts.

Table 5: Firm-level estimates on interest rate

	Interest Rate			Not subsidized IR		
	(1)	(2)	(3)	(4)	(5)	(6)
lag_4q_CR	0.020***	0.020***	0.011**	0.006	0.007	-0.011**
	(0.004)	(0.004)	(0.004)	(0.005)	(0.005)	(0.005)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Sector x Time FE	No	Yes	Yes	No	Yes	Yes
Bank x Time FE	No	No	Yes	No	No	Yes
Cluster	Firm	Firm	Firm	Firm	Firm	Firm
Sample	Full	Full	Full	Full NS	Full NS	Full NS
Observations	264,540	264,540	264,540	204,218	204,218	204,218
R^2	0.754	0.757	0.762	0.730	0.731	0.744
Demand corr. CR	0.048	0.048	0.038	0.032	0.038	0.020
Note:						*p<0.1; **p<0.05; ***p<0.01

The table shows the coefficient estimates of capital requirements (CR) on interest rates at the firm level. The dependent variable is the weighted mean interest rate for the given firm across banks; the variable of interest is one-year lagged capital requirements. Standard errors are shown in parentheses below the estimated coefficient, asterisks indicate statistical significance. Estimated models progressively include fixed effects (FEs). Model (1) to (3) uses regular average interest rates as the dependent variable; in Model (4) – (6), it is a conditional average of the not subsidized *loans. Error terms are clustered at the firm level in all cases. Demand corrected estimates calculated using Eq. (3) are presented at the bottom.*

Looking at Table 6, we document that increasing CRs harm the firm's activity and investments. Our saturated models with and without bank-time FEs consistently show negative estimates of total assets, net sales, fixed assets, and employment figures of the firm. Our proxy for investments, the fixed assets measure, is the most sensitive firm outcome, with a sensitivity of around 1.5%. Estimates suggest that a firm with a 1 percentage point increase in its CR shrinks its total assets by 0.5%, and its net revenues drop by 1%. Number of employees is less sensitive, with an estimate of 0.2%. The results show that capital requirement changes at the firm level have real economic consequences.

Table 6: Real impacts

	Total Assets		Sales		Fixed assets		Employment	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
CR	-0.005***	-0.005***	-0.011***	-0.010***	-0.016***	-0.015***	-0.002***	-0.002***
	(0.001)	(0.001)	(0.003)	(0.003)	(0.003)	(0.003)	(0.0004)	(0.0004)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sector x Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank x Time FE	No	Yes	No	Yes	No	Yes	No	Yes
Cluster	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm
Sample	Full	Full	Full	Full	Full	Full	Full	Full
Observations	211,088	211,088	211,08	211,08	210,953	210,953	211,091	211,091
R^2	0.978	0.978	0.916	0.916	0.925	0.925	0.972	0.972

The table shows the coefficient estimates of capital requirements (CR) impacts on the firm's balance sheet and real activity. The dependent variable in Model (1) and (2) is the total assets of the firm, in Model (3) and (4) it is the net *sales of the firm, in Model (5) and (6) it is its fixed assets, in Model (7) and (8) it is the number of employees. All dependent variables are log-transformed. Standard errors are shown in parentheses below the estimated coefficient, asterisks indicate statistical significance. Estimated models progressively include fixed effects (FEs).*

1.3.3. Loan application results

We document an increased intensity of loan applications from firms with recently increased CRs towards banks with no prior relation. We have no direct data on firms' loan applications, but we have an indirect proxy for loan applications, similar to Goel et al. (2024). The Central Credit Information System (CCIS) is open for banks to assess the credit performance of their loan applicants in exchange for a small fee. This database contains loan histories of firms, including outstanding amounts and payment delinquencies. The central bank collects data on queries initiated by banks to collect this information. We use bank queries that collect information on firms with no lender-borrower relationship at the time of the query as our loan application proxy. We limit our proxy to no lender-borrower relationship to filter out loan performance monitoring since we want to measure loan applications for new banks from the firm's point of view. Our loan application proxy strongly predicts whether firms obtain new banking relationships in a given period (see Table A4 in the Appendix).

We see that the unconditional probability of applying for a loan at a new bank for firms with increased firm-level CR in the same period is higher by 2.5 percentage points than after a decrease or unchanged firm-level CRs (Table 7). Furthermore, we also estimate the coefficient of lagged firm-level CRs on loan application using our usual specification described in Eq. (2). Our results imply that this effect is statistically significant across all models (Table 8) but smaller in magnitude. The estimated coefficients imply a 1 percent increase in loan application probability in the period 9-12 months after a 1 pps increase in firm-level CRs. We repeat the estimation process for actual new banking relations and observe similar significant results, as the number of new banking relationships of firms increases by 2 percent per 1 pp CR increase.

Table 7: Loan applications to non-related banks

CR change	Binary application dummy to non-related bank	Number of applications to non-related bank	Number of obs.
ΔCR =< 0	0.109	0.128	192630
0 < ΔCR	0.136	0.163	91987

Table shows probability of loan applications to non-related banks based on CR changes.

Table 8: Firm-level estimates on loan applications to non-related banks and on new bank relations

	Application to new bank			Number of new bank relations		
	(1)	(2)	(3)	(1)	(2)	(3)
lag_4q_CR	0.001***	0.001***	0.001	0.002***	0.002***	0.003***
	(0.0003)	(0.0003)	(0.0003)	(0.0004)	(0.0004)	(0.0003)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	-	-	Yes	-	-
Sector x Time FE	No	Yes	Yes	No	Yes	Yes
Bank x Time FEs	No	No	Yes	No	No	Yes
Cluster	Firm	Firm	Firm	Firm	Firm	Firm
Sample	Full	Full	Full	Full	Full	Full
Observations	284,617	284,617	284,617	283,323	283,323	283,323
R^2	0.475	0.477	0.479	0.361	0.364	0.609
Note:						*p<0.1; **p<0.05; ***p<0.01

Table shows the coefficient estimates of capital requirements (CR) on loan application and new banking relation of firms. The left panel row shows results for loan applications in a given quarter, and the right panel shows results for the number of new banking relationships. The variable of interest is one-year lagged capital requirements at the firm-level. Standard errors are shown in parentheses below the estimated coefficient, asterisks indicate statistical significance. Estimated models progressively include fixed effects (FEs). Error terms are clustered at the firm level in all cases.

1.3.4. Heterogeneous impacts

Now, we turn to the heterogeneity assessment of our results. We have shown that banks' lending behavior and, as a result, firms' credit is strongly impacted by capital requirement changes, and even their real economic indicators are sensitive. We now evaluate which firm-bank relations and which firms are the most sensitive to such changes. Firstly, we assess the credit effect differences between foreign banks using mostly IRB and domestic banks using mostly SA approaches. We also look at the firm-level implications of this difference. Secondly, we estimate the firm-level impacts on credit and real economic outcomes across small, medium, and large firms using multiple size measures.

Table 9 shows the estimated bank-level firm CR changes' impacts on exposure and interest rates for domestic and foreign banks separately. Similarly to the previous granular firm-bank pair analysis, we saturate our model step by step with bank-time and firm-time FEs and also estimate a bank-time FE model to the multibank sample separately both for our EAD (column (1)-(3)) and interest rate (column (4)-(7)) models. Results for interest rates of non-subsidized loans are also estimated (column (7)). Our results point towards significant differences between foreign and domestic bank CR sensitivity. Both volume and price impacts are more prominent for domestic banks.

Next, we show that this difference between foreign (IRB) and domestic (SA) banks is also relevant at the firm level. Looking at Table 10, we document the results of firms with foreign banks and firms without foreign banks, once again on exposures and interest rates. The estimates show that while for firms without foreign bank relations, changes in firm-level CR translate to a substantial reduction in credit and an increase in interest rates, for firms with a relationship to foreign banks, these effects are smaller and sometimes non-significant.

While the estimated impacts being lower for foreign banks align with finance theory, it is unclear whether these impacts are driven by the foreign bank effect or by the approach used (SA or IRB) to determine risk weights and capital requirements. Capital requirements determined by the standard approach change less but tend to have a larger impact on lending, while CRs based on internal approaches change more frequently but tend to have a smaller impact on lending based on our estimates.

Table 9: Firm-bank pair estimates on exposure at default for foreign and home banks

	log EAD			Interest rate			Interest rate No subsidy
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
lag_4q_CR	-0.185***	-0.281***	-0.341***	0.142***	0.197***	0.223***	0.171***
	(0.048)	(0.052)	(0.019)	(0.020)	(0.025)	(0.030)	(0.036)
lag_4q_CR:foreign	0.146**	0.219***	0.269***	-0.124**	-0.155**	-0.153***	-0.108**
	(0.053)	(0.061)	(0.030)	(0.041)	(0.050)	(0.040)	(0.042)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank x Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm x Time FE	No	No	Yes	No	No	Yes	Yes
Cluster	Bank & Firm	Bank & Firm	Bank & Firm	Bank & Firm	Bank & Firm	Bank & Firm	Bank & Firm
Sample	Full	Multibanks	Multibanks	Full	Multibanks	Multibanks	NS &Multib.
Observations	1,261,701	451,582	451,582	1,161,740	428,998	428,998	327,943
R^2	0.764	0.613	0.904	0.661	0.505	0.897	0.916

Table shows the coefficient estimates of capital requirements (CR) on lending volume and interest rate by home and foreign lending institutions. The first row shows results for CR without interaction, and the second row shows CR-foreign bank dummy interaction. The dependent variables are the log of exposure at default ((1) – (3) columns), the average interest rate ((4) – (6) columns), and the non-subsidized interest rate ((7) column) at the bank for the given firm. The variable of interest is one-year lagged capital requirements. Standard errors are shown in parentheses below the estimated coefficient, asterisks indicate statistical significance. Estimated models progressively include fixed effects (FEs). Model (3) sample is limited to firms with multiple bank lenders to identify firm-period FEs. Error terms are double clustered at the bank and firm levels in all cases.

Table 10: Volume and interest rate estimates for firms with and without relation to foreign banks

	Total EAD			Interest rate		
	(1)	(2)	(3)	(4)	(5)	(6)
lag CR: Foreign bank	-0.001	-0.001	-0.007***	0.004	0.005	0.006
	(0.002)	(0.002)	(0.001)	(0.005)	(0.005)	(0.005)
lag CR: No foreign bank	-0.109***	-0.108***	-0.077***	0.078***	0.076***	0.027***
	(0.002)	(0.002)	(0.002)	(0.007)	(0.007)	(0.007)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Sector x Time FE	No	Yes	Yes	No	Yes	Yes
Bank x Time FE	No	No	Yes	No	No	Yes
Cluster	Firm	Firm	Firm	Firm	Firm	Firm
Sample	Full	Full	Full	Full	Full	Full
Observations	267,934	267,934	267,934	247,886	247,886	247,886
R^2	0.893	0.893	0.901	0.764	0.766	0.772

The table shows the coefficient estimates of capital requirements (CR) on interest rates at the firm level. The dependent variable in Model (1) to (3) is exposure at default, in Model (4) – (6) it is the average interest rate for the given firm across banks, the variable of interest is one year lagged capital requirements interacted with foreign bank relationship factor. The first row shows estimates for firms related to foreign banks, and the second row shows estimates for firms without. Standard errors are shown in parentheses below the estimated coefficient, asterisks indicate statistical significance. Estimated models progressively include fixed effects (FEs). Error terms are clustered at the firm level in all cases.

Looking at Table 11, we explore how firm-level CR changes impact firms of different sizes. We estimate the impacts on firm-level exposures and interest rates, as well as assets, sales, fixed assets, and employment, using sales and employment as size proxies. We split all firms in our sample into size quartiles based on their relative size compared to others at the beginning of the sample or the first time they exist in our sample.

Firm-level CR changes do not seem to affect more smaller firms in the case of credit volume (columns (1) and (2)) and interest rate (columns (3) and (4)). Interestingly, credit volume and interest rates toward larger firms seem to be more sensitive to CR changes. However, small firms tend to be more heavily impacted if we analyze real economic outcomes. Especially for assets (columns (5) and (6)) and employment (columns (11) and (12)), where there is a monotonic relation between firm size and CR sensitivity, using both size measures. Our investment proxy, fixed asset size, is two times as sensitive for small firms than for large firms (columns (7) and (8)), similar to total asset size. Sales (columns (9) and (10)) change differences are even more pronounced for small and large firms; small firms are two or four times more sensitive, with some uncertainty around the estimates in this case.

Table 11: Heterogeneity of real impacts across firm sizes

Dependent variable:	EAD		IR		Assets		Sales		Fixed Assets		Employment	
Size measure:	Sales	Employ.	Sales	Employ.	Sales	Employ.	Sales	Employ.	Sales	Employ.	Sales	Employ.
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
CR:Q1	-0.010***	-0.027***	0.023**	0.027**	-0.008***	-0.007***	-0.023***	-0.011	-0.021**	-0.024**	-0.004***	-0.005***
	(0.003)	(0.005)	(0.011)	(0.012)	(0.002)	(0.002)	(0.009)	(0.009)	(0.009)	(0.011)	(0.001)	(0.001)
CR:Q2	-0.018***	-0.016***	0.032***	0.030***	-0.004***	-0.006***	-0.009**	-0.017***	-0.016***	-0.014***	-0.002***	-0.002***
	(0.003)	(0.003)	(0.012)	(0.011)	(0.001)	(0.001)	(0.004)	(0.005)	(0.004)	(0.005)	(0.001)	(0.001)
CR:Q3	-0.037***	-0.029***	0.031***	0.022**	-0.004***	-0.004***	-0.003	-0.007***	-0.013***	-0.012***	-0.001	-0.001**
	(0.004)	(0.003)	(0.010)	(0.010)	(0.001)	(0.001)	(0.003)	(0.002)	(0.003)	(0.003)	(0.001)	(0.001)
CR:Q4	-0.059***	-0.056***	0.036***	0.044***	-0.003***	-0.004***	-0.006***	-0.006***	-0.012***	-0.014***	-0.001	0.001
	(0.005)	(0.004)	(0.009)	(0.009)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.003)	(0.001)	(0.001)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sector x Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank x Time FE	No	No	No	No	No	No	No	No	No	No	No	No
Cluster	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm
Sample	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full
Observations	189,437	189,436	177,065	177,064	196,651	196,65	196,645	196,644	196,553	196,552	196,654	196,653
R^2	0.886	0.886	0.729	0.729	0.979	0.979	0.914	0.914	0.923	0.923	0.972	0.972

Table shows the heterogenous coefficient estimates of capital requirements (CR) impacts on the firm's balance sheet and real activity for each firm size quarter. The dependent variable is described by the first row. In Model (1) and (2) it is the exposure of the firm, in Model (3) and (4), it is the average interest rate of the firm, in Model (5) and (6) it is total assets of the firm, in Model (7) and (8) it is the net sales of the firm, in Model (9) and (10) it is its fixed assets, in Model (11) and (12) it is the number of employees. Below the dependent variable, the size metric used for grouping is described, with sales in odd columns and employment in even ones. The one-year lagged capital requirements interacted with size quarters from the lowest size (Q1) to the largest (Q4). Standard errors are shown in parentheses below the estimated coefficient, asterisks indicate statistical significance. Estimated models progressively include fixed effects (FEs). Error terms are clustered at the firm level in all cases.

1.3.5. Robustness and placebo test results

We perform a placebo test to show that our results are not driven by spurious correlation. In our placebo set up, we test whether future CR changes have substantial impact on lending. Firstly, we estimate a first differences panel model, where the dependent variable is the log-difference of exposure of default and our variables of interest are the differences in capital requirements and its lags.

$$\Delta\log\ EAD_t = \alpha + \ \beta_0 \cdot \Delta K_t + \beta_{-1} \cdot \Delta K_{t-1} + \beta_{-2} \cdot \Delta K_{t-2} + \beta_{-3} \cdot \Delta K_{t-3} + \gamma_{f,t} + \delta_{b,t} + \varepsilon_{t,f,b} \qquad (4)$$

In our placebo specifications, we include a lead term, ΔK_{t+1} to assess whether capital requirements shocks in the future effect lending volumes today.

$$\Delta\log\ EAD_t = \alpha + \ \beta_1 \cdot \Delta K_{t+1} + \ \beta_0 \cdot \Delta K_t + \beta_{-1} \cdot \Delta K_{t-1} + \beta_{-2} \cdot \Delta K_{t-2} + \gamma_{f,t} + \delta_{b,t} + \varepsilon_{t,f,b} \qquad (5)$$

The results of this test are shown in Table 12. The estimates imply that if the future value of CR has any impact, it is marginal, although it is significant in the firm-time fixed effects specification. Even in that case, more than 92 percent of the impact of capital requirement shocks on volume is due to the past changes in CR. Additionally, the baseline model estimates also show that CR shocks mostly translate to lending impacts relatively quickly. Most impacts are incorporated 6 months after the initial CR shock.

Table 12: Placebo test

	Δlog EAD			
	(1)	(2)	(3)	(4)
lead1q_CR		-0.005		-0.006**
		(0.003)		(0.002)
diff_CR	-0.075	-0.059	-0.074***	-0.056**
	(0.042)	(0.034)	(0.021)	(0.017)
lag1q_diff_CR	-0.072	-0.012	-0.070**	-0.010*
	(0.043)	(0.009)	(0.022)	(0.005)
lag2q_diff_CR	-0.019	-0.004	-0.018**	-0.004
	(0.013)	(0.004)	(0.008)	(0.003)
lag3q_diff_CR	-0.009		-0.008*	
	(0.006)		(0.004)	
Time FE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Bank x Time FE	Yes	Yes	Yes	Yes
Firm x Time FE	No	No	Yes	Yes
Cluster	Firm & Bank	Firm & Bank	Firm & Bank	Firm & Bank
Sample	Full	Full	Multibank	Multibank
Observations	1,383,532	1,383,532	1,383,532	1,383,532
R2	0.215	0.124	0.852	0.844
Note:			*p<0.1; **p<0.05; ***p<0.01	

Table shows the coefficient estimates of capital requirements (CR) differences and a lead, placebo term on lending volume. The dependent variables are the log of exposure at default at the bank for the given firm. Column (1) and (3) shows the results of a first difference panel model, Column (2) and (4) shows the results with the placebo term. Standard errors are shown in parentheses below the estimated coefficient, asterisks indicate statistical significance. Estimated models progressively include fixed effects (FEs). The sample is limited to firms with multiple bank lenders to identify firm-period FEs in columns (3) and (4). Error terms are double clustered at the bank and firm levels in all cases.

We estimate our model specifications with various modifications to assess the robustness of our results. Whether we estimate our models with our original or winsorized variables does not change our results, implying that these estimated effects are not driven by outliers (Table A1). We also include the logarithm of collateral values to account for the effect of risk mitigation techniques but do not change our results either (Table A2). We test whether movements in foreign currencies drive our results, but our estimates where credit volume was calculated using initial foreign exchange rates or floating ones resulted in very similar values. Similarly, average interest rate values based only on HUF loans have very similar estimates to those of our other estimated interest rate sensitivities. We estimate impacts on different subsamples, across different years and by leaving out different banks of the sample to assess robustness. The estimates are relatively stable across time and bank samples (Table A3).

One last concern is that our results are driven by heterogenous beliefs about a firm's risk by banks and not by CRs. While we cannot observe banks' risk perception, we can assess whether our results are driven by different reaction times of banks to risk shocks affecting firms, a potential source of heterogeneity in risk perception. Suppose the following. Bank A observed a risk shock affecting a firm and decreased lending towards the firm because, while parallelly, it changed capital requirements. Then, one period later, Bank B also sensed the increased risk and limited lending to the firm while parallelly increasing capital requirements. Bank A has not changed anything this time since it had already decreased credit supply in the previous period. In this scenario, the estimated effect in Eq. (1) (β) will be distorted because the risk shock in the error term ($\varepsilon_{t,f,b}$) correlates with the capital requirement ($K_{(t-1),f,b}$). To tackle this issue, one can include the CR of Bank B in the second period when estimating the effect of Bank A in the first period, to control for the late realization of the credit risk shock by other banks. To control for the early risk observation by other banks, one can include the CR of Bank A in the first period, when estimating the effect of Bank B in the second period.

Formally, we modify Eq. (1) to include a double lagged cross averaged CR term ($\overline{K}_{(t-2),f,-b}$), which is the equally weighted mean of all banks' CR except bank *b*, to capture any effects that might be the result of delayed risk monitoring by banks. To control for early realization, we include the current period's cross averaged CR term ($\overline{K}_{t,f,-b}$) in Eq. (6). Regarding the coefficients of the current and the double lagged cross averaged CRs, if there are substantial delays in risk monitoring across banks, we would estimate significantly negative coefficients (θ, ϑ) for those control variables in Eq. (6). Note that if Bank A changes CRs for a firm, and later other banks do the same, the early warning indicator of the double lagged cross averaged CR would be positive for the late comer banks and those banks lagged CRs ($K_{(t-1),f,b}$) would not be significant if banks only reacted to risk changes. Similarly, the late realization indicator of the current cross-averaged CR would be positive for Bank A (since the next period other banks realize the risk shock too), and the lagged CRs of Bank A would only be significant if it reacted to the CR shock. To sum up, we would estimate that the β coefficient is not significantly different from zero in Eq. (6) if banks only responded to a risk channel.

$$Y_{t,f,b} = \alpha + \beta \cdot K_{(t-1),f,b} + \theta \cdot \overline{K}_{t,f,-b} + \vartheta \cdot \overline{K}_{(t-2),f,-b} + \gamma_{f,t} + \delta_{b,t} + \varepsilon_{t,f,b} \quad (6)$$

We estimate Eq. (6) using multiple lag periods for the double-lagged cross CR term (5, 6, and 8 quarters) to assess a variety of response time differences. Results are shown in Table 13. Generally, our results show significant CR effects both for lending volume and for interest rate, implying that sequential risk observation by banks is not the driver behind our significant CR coefficient estimates. If we clustered the errors on the firm level, all β coefficients would be significant even at the 1 percent level. The positive estimates on current and lagged cross-averaged terms for volume models imply that it is not the risk perception narrative that best describes the situation. Overall, this also weakens arguments on banks' heterogeneous risk beliefs, as these must be stable across time periods and firm risk profiles to impact our estimates.

Table 13: Results in heterogenous risk beliefs set up

	log EAD			Interest rate		
	(1)	(2)	(3)	(4)	(5)	(6)
lag_4q_CR	-0.054**	-0.045***	-0.045***	0.033	0.048**	0.069***
	(0.017)	(0.013)	(0.013)	(0.019)	(0.017)	(0.016)
crossmean_CR	0.143***	0.133**	0.114**	-0.063**	-0.051*	-0.018
	(0.009)	(0.040)	(0.040)	(0.025)	(0.023)	(0.016)
crossmean_lag_5q_CR	0.034***			-0.039**		
	(0.006)			(0.014)		
crossmean_lag_6q_CR		0.056***			-0.022	
		(0.009)			(0.017)	
crossmean_lag_8q_CR			0.072***			0.007
			(0.011)			(0.023)
Bank x Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm x Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Cluster	Firm & Bank	Firm & Bank	Firm & Bank	Firm & Bank	Firm & Bank	Firm & Bank
Sample	Multibank	Multibank	Multibank	Multibank	Multibank	Multibank
Observations	347,338	293,764	200,882	330,977	279,904	191,085
R^2	0.657	0.662	0.670	0.611	0.605	0.594
Note:						*p<0.1; **p<0.05; ***p<0.01

Table shows the coefficient estimates of capital requirements (CR) on lending volume and interest rate when lead and lag cross averaged CRs terms of other banks are included. The dependent variables are the log of exposure at default ((1) – (3) columns), and the average interest rate ((4) – (6) columns) at the bank for the given firm. The first column shows the results with a 5 quarter lag for the cross averaged term, the second with 6, the third with 8 for each dependent variable. The variable of interest is one-year lagged capital requirements. Standard errors are shown in parentheses below the estimated coefficient, asterisks indicate statistical significance. Estimated models include bank-time and firm-time fixed effects (FEs). The sample is limited to firms with multiple bank lenders to identify firm-period FEs. Error terms are double clustered at the bank and firm levels in all cases.

1.4. Discussion

Our findings confirm that bank capital requirements have significant and multifaceted effects on corporate lending and firm activity. The results suggest that increases in capital requirements reduce credit volumes and raise interest rates at the bank-firm level, with effects persisting at the aggregate firm level. These findings reinforce the view that capital regulation shapes not only bank balance sheet behavior but also has measurable real-economy consequences.

Our range of estimates of 8-17 percent is substantially higher than the results of Fraisse et al. (2020) and is closer in magnitude to Gropp et al. (2019) with 9 and Aiyar et al. (2014) with 5.7 – 8 percent. The higher impact of capital requirements on lending could be related to less developed banking and capital markets and the fact that multibank firms are more sensitive to shocks in firm-bank level capital requirements. Multibank sensitivity can result from credit substitution effects, which are less costly for multibank firms, as others have to build up a new banking relationship to obtain loans from different sources while they already have other existing relations. Based on our estimates, the whole sample of firms is 67 percent as sensitive to CR shocks as the multibank firms, which imply that the most likely estimate for the whole sample would be 11.2 percent, which is more similar to previous estimates in the literature. Similarly to volume, our range of interest rate impact estimates is in line with the upper range of results in the literature (Benetton et al., 2021). Overall, it seems impacted firm-bank relations adjust to changes in their capital requirements by both quantities and prices.

One key contribution of this study is the distinction between partial and general equilibrium effects of CR shocks. The firm-level impacts of CR changes tend to be lower than our bank-firm-level estimates, implying that general equilibrium effects are lower in magnitude than partial effects. Firms can partially mitigate these credit supply shocks by seeking alternative sources of bank financing. One of the ways firms adapt to new circumstances is by applying for loans at banks where they had no prior borrowing relationship. This "application channel" provides a mechanism through which firms attempt to offset tighter credit, highlighting a potentially important adjustment path for policy consideration. The existence of this channel suggests that CR shocks are different from monetary policy induced shocks, as Jiménez et al. (2012) found that firms affected by monetary policy shocks cannot offset the resultant credit restriction by applying to other banks. Our previously shown impact difference between single bank and multibank firms could also be partially attributed to multibank firms' lower cost of seeking alternative sources of bank financing. However, firm-level impacts are still statistically significant and economically substantial.

Our findings are in line with other studies assessing the impact of firm-level CR changes on real economic activity (Fraisse et al., 2020; Gropp et al., 2019), supporting the hypothesis that credit supply shocks driven by regulation can propagate to the real economy. Investment volume by firms tends to be the most impacted by CR changes. Generally, investment decisions are sensitive to firms' borrowing shocks from bank supply shocks (Amiti & Weinstein, 2018), we add to the growing evidence that CR shocks are similar. Similarly to Fraisse et al. (2020), our estimates on employment are significant but smaller in magnitude. It confirms that firm-level credit shocks have a detrimental effect on employment. However, during the covered period in Hungary, the labor market was very tight, with a low level of unemployment, which could have dampened the magnitude of our estimates. Our results - smaller firms being more prone to credit disruptions, especially bank financing - align with previous results in the literature. Smaller, younger, poorly capitalized firms were identified as more prone to CR changes (Fraisse et al., 2020), similar to unlisted firms (Gropp et al., 2019).

A novel result is the documented role of foreign banks, and IRB approaches in shaping these dynamics. Firms borrowing from domestic banks—who primarily use the Standardized Approach for capital regulation—experience stronger reductions in lending than those borrowing from foreign subsidiaries operating under IRB models. This suggests that internal capital market access - the parent banks can obtain equity financing more easily compared to domestic banks - and risk-modeling flexibility provides a buffer for foreign banks, allowing them to shield their clients from CR shocks. At the firm level, this translates into smaller credit and interest rate impacts for firms with foreign bank ties. These findings align with prior work (e.g., De Haas & Van Lelyveld, 2010), reinforcing the role of bank heterogeneity in shaping the transmission of regulation.

We add further evidence that on top of risk perception, capital requirements in themselves have substantial impacts on bank lending. By controlling for delays in banks' risk perception, we still find significant CR impacts on lending, reinforcing the exogeneity of our treatment variable. Additionally, we conduct placebo tests using future capital requirements to rule out reverse causality and show that over 90% of observed lending responses stem from past CR changes, not anticipatory behavior. We further validate our findings by accounting for the risk reduction effects of collaterals, which is rarely assessed in the literature. Together, these robustness tests provide a comprehensive framework for addressing endogeneity and reinforce the credibility of our causal inference.

Regarding policy recommendations, our results are relevant for supervisory authorities and central banks evaluating the pros and cons of modifying capital requirement frameworks. The estimated general equilibrium effects show that increasing the general level of capital requirements can result in substantial credit disruption. A gradual phase-in of such measures is recommended to limit these consequences. Measures to support lending to smaller firms during a CR increase cycle, such as the SME supporting factor implemented in the EU to mitigate the impacts of stricter capital rules by the CRR and CRD IV, could mitigate adverse effects on the most vulnerable companies. Accommodative monetary policy can also mitigate the costs of adverse CR shocks. Additionally, our results are especially relevant for the growing policies on differentiated capital requirements. Based on our estimates, macroprudential policymakers aiming to limit credit booms in targeted sectors can calibrate the sectoral systemic risk buffer. Similarly, expected impacts of the SME supporting factor can be calibrated, and policymakers assessing the introduction of capital regulations related to climate-related risks can also inform on the potential lending and real impacts of a dirty penalizing factor (Miguel et al., 2024) or a green supporting factor (Oehmke & Opp, 2022).

1.5. Conclusion

This study examines the impacts of capital requirements on corporate lending and the broader economy, using Hungary as a case study. We find that increases in CRs significantly reduce bank lending volumes and increase interest rates at the firm-bank level, with particularly strong partial equilibrium effects for multibank firms. Firms partially offset these impacts by diversifying lenders, which dampens general equilibrium effects on credit volume and interest rates. Real economic consequences, such as investment, revenue, and employment reductions, remain substantial. Notably, smaller firms and those reliant on domestic banks are disproportionately affected, underscoring the differentiated effects of CRs based on firm size. These findings align with existing literature but provide novel insights into the role of granular bank-firm relationships in CR impact transmission.

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1.6. Appendix

Table A1: Firm-bank pair estimates on exposure at default using winsorized variables

	log EAD winsor			
	(1)	(2)	(3)	(4)
lag_4q_CR_winsor	-0.115***	-0.119***	-0.181***	-0.222***
	(0.033)	(0.034)	(0.040)	(0.029)
Time FE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes
Bank x Time FE	No	Yes	Yes	Yes
Firm x Time FE	No	No	No	Yes
Cluster	Bank and Firm	Bank and Firm	Bank and Firm	Bank and Firm
Sample	Full	Full	Multibanks	Multibanks
Observations	1,261,701	1,261,701	451,582	1,261,701
R2	0.752	0.759	0.600	0.902

Table shows the same content as Table 1, but with winsorized variables. Standard errors are shown in parentheses below the estimated coefficient, asterisks indicate statistical significance. Estimated models progressively include fixed effects (FEs) across Model (1) to (4). The sample in Model (3) and (4) is limited to firms with multiple bank lenders to identify firm-period FEs. Error terms are double clustered at the bank and firm levels in all cases.

Table A2: Robustness checks for firm-bank pair estimates on exposure at default

	log_EAD			
	(1)	(2)	(3)	(4)
lag_4q_CR	-0.088**	-0.174***	-0.098**	-0.207***
	(0.038)	(0.037)	(0.033)	(0.032)
log_COLL	0.029***	0.035***		
	(0.004)	(0.008)		
Time FE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes
Bank x Time FE	No	Yes	No	Yes
Firm x Time FE	No	Yes	No	Yes
Cluster	Bank & Firm	Bank & Firm	Bank & Firm	Bank & Firm
Sample	Full	Multibanks	Performing	Perf. & Multi.
Observations	1,261,701	1,261,701	1,104,811	1,104,811
R^2	0.755	0.900	0.775	0.911

Table shows various robustness checks for the coefficient estimates of capital requirements on lending volume in Eq. 1. The dependent variable is the logarithm of exposure at default, the variable of interest in the 4 estimated panel regressions is one year lagged capital requirements. In Model (1) and (2) we include the logarithm of collateral as a potential confounder, in Model (3) and (4) we limit our sample to performing loans. Standard errors are shown in parentheses below the estimated coefficient, asterisks indicate statistical significance. Estimated models progressively include fixed effects (FEs) across Model (1) to (4). We further limit our sample to firms with multiple bank lenders to identify firm-period FEs in Model (2) and (4). Error terms are double clustered at the bank and firm levels in all cases.

Table A3: Firm-bank pair estimates on exposure at default on subsamples

log EAD					
Estimate	Std.error	Sample	Estimate	Std.error	Sample without bank
-0.096	0.017	2020	-0.168	0.036	Bank1
-0.139	0.029	2021	-0.168	0.036	Bank2
-0.165	0.032	2022	-0.271	0.024	Bank3
-0.180	0.038	2023	-0.166	0.036	Bank4
-0.182	0.046	2024	-0.108	0.020	Bank5
			-0.133	0.025	Bank6
			-0.163	0.036	Bank7
			-0.171	0.041	Bank8
			-0.162	0.034	Bank9

Table shows various robustness checks for the coefficient estimates of capital requirements on lending volume in Eq. 1 across different subsamples on bank-firm level. The dependent variable is the logarithm of exposure at default, the variable of interest in the 4 estimated panel regressions is one year lagged capital requirements. The left panel shoes results for different periods, the right panel for different subsamples of banks, created by leaving out one banks observations from the sample.

Table A4: Loan applications to non-related banks and new bank relations

	n_new_bank		bin_new_bank	
	(1)	(2)	(3)	(4)
bin_bank_query_nrel	0.069***		0.060***	
	(0.002)		(0.002)	
bin_bank_query_nrel_y		0.098***		0.087***
		(0.002)		(0.002)
Constant	0.134***	0.123***	0.127***	0.117***
	(0.001)	(0.001)	(0.001)	(0.001)
Sample	Full	Full	Full	Full
Observations	297,838	297,838	297,838	297,838
R^2	0.004	0.011	0.003	0.010
Note:	*p<0.1; **p<0.05; ***p<0.01			

The table shows how our loan application proxy is related to new banking relations. The dependent variable is the number of new bank relations in Column (1) and (2), and a dummy on new banking relation in Column (3) and (4). The variable of interest are dummies loan application proxies in the last quarter (Column (1) and (3)) and in the last year (Column (2) and (4)).