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The effect of bank capital on lending: Does liquidity matter?

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ABSTRACT

This paper uses a sample of quarterly observations of insured US commercial banks to examine whether the effect of bank capital on lending differs depending upon the level of bank liquidity. We find that the effect of an increase in bank capital on credit growth, defined as growth rate of net loans and unused commitments, is positively associated with the level of bank liquidity only for large banks and that this positive relationship has been more substantial during the recent financial crisis period. This result suggests that bank capital exerts a significantly positive effect on lending only after large banks retain sufficient liquid assets.

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1. Introduction

After the recent financial crisis, ensuring the financial stability of banking systems has been considered an imperative for regulators, academics, and policymakers. In particular, with the Basel Committee on Banking Supervision (BCBS) at the center of deliberations, regulators and policymakers have highlighted the critical importance to such stability of sufficient capital buffers and sound liquidity risk management. A result of these efforts is the international endorsement of Basel III, which requires enhanced quality and quantity of capital, a sufficient amount of stable funding, and the liquidity of bank assets. This initiative is based on the belief that banks with sufficient capital, liquid assets, and stable funding structures can more effectively maintain their intermediation capacity amid external negative economic shocks.

As emphasized by the Basel Committee, a main objective of reforms to strengthen global capital and liquidity rules is building a foundation for sustainable economic growth with a strong and resilient banking system (BCBS, 2011). That is, losses caused by spillovers from negative shocks in the financial sector to the real economy should be prevented. In this context, considerable research has examined the effects of financial shocks on real economic activity and the procyclical features of risk-based capital ratios, which can further worsen financial shocks by forcing banks to reduce credit supply when such a supply is most required.

Understanding the relationship between bank capital and lending is a key issue discussed in other bank-related studies. As Berrospide and Edge (2010) highlight, quantifying the effect of bank capital on bank credit supply is one of the most fundamental research problems requiring resolution in verifying the link between the financial sector and real activity. For example, bank capital constitutes a principal component of Bayoumi and Malander's (2008) framework for macro-financial linkage. In this framework, the relationship between bank capital and lending standards is the first link. Banks make their lending standards more stringent following a negative shock to capital ratio, thereby reducing credit volume. Another important consideration is the "bank-capital channel" of monetary policy. Van den Heuvel (2002), Gambacorta and Mistrulli (2004), and Meh (2011) emphasize the importance of the bank-capital channel whereby monetary policy and shocks to bank capital affect bank lending. Comprehending the effect of monetary policy on the real economy is therefore challenging without verifying the relationship between bank capital and lending.

During the recent financial crisis, a shortage of capital was observed as a key factor limiting banks' ability to issue loans. Hence, many studies that examine the effect of bank capital on lending have recently emerged (see Berrospide and Edge, 2010; Gambacorta and Marques-Ibanez, 2011; Carlson et al., 2011; Brei et al., 2013). However, Fig. 1 indicates that a shortage of capital is

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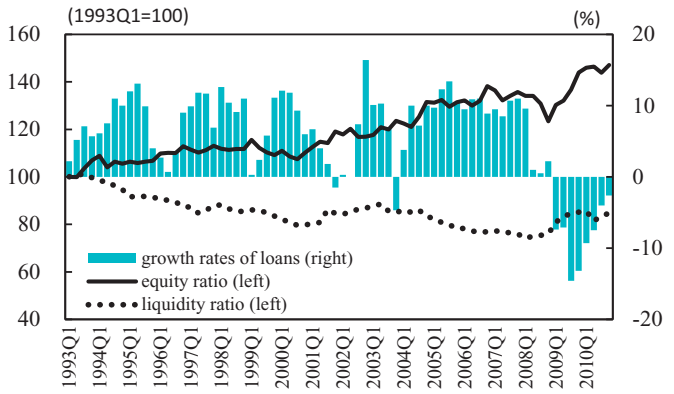

Fig. 1. Growth rates of loans and the trend in proportions of liquid assets and equity.
Notes: Loans are total loans and leases on the balance sheet excluding federal funds sold to, reverse RPs with, and loans made to commercial banks. Liquidity ratio = (cash + securities + interbank loans + federal funds and reverse RPs with banks)/total assets. Equity = asset – liability.
Source: Federal Reserve Bank H.8. Assets and liabilities of commercial banks in the United States.

insufficient to explain sudden contractions in bank loans because equity ratio has gradually increased in every year except 2008, which is considered the most severe year of the crisis. Some scholars focus on other factors that have slowed bank lending during the recent financial crisis. For example, Corentt et al. (2011), Berrospide (2013), and Ivashina and Scharfstein (2010) highlight the effect of bank liquidity on lending. Cornett et al. (2011) and Berrospide (2013) find that banks' efforts to manage liquidity caused bank lending to decline during the recent crisis. Similarly, Ivashina and Scharfstein (2010) show that bank lending decreases more substantially for banks with less access to deposit financing and higher exposure to credit line drawdowns.

The current study is grounded in the conclusions asserted in the literature, which emphasize the importance of other bank-specific characteristics to bank lending (Berrospide and Edge, 2010; Gambacorta and Marques-Ibanez, 2011). To date, research has focused on a linear relationship between bank capital and lending or has examined whether a structural change in response to external shocks occurs. To our knowledge, no studies have examined the interaction effect of bank capital and liquidity on lending. To examine this interaction, we use the 1993 Q1–2010 Q4 unbalanced quarterly observations of insured US commercial banks to determine whether the effect of bank capital on lending changes depending upon the level of bank liquidity.

The main findings are as follows. For large banks, the effect of an increase in bank capital ratio on credit growth, defined as growth rate of net loans on the balance sheet plus unused commitments unrepresented on the balance sheet, is positively associated with the level of bank liquidity. This finding suggests that the effect of an increase in capital ratio on credit growth is significantly negative for low liquidity ratios, becoming significantly positive only after large banks retain sufficient liquid assets. This interaction effect is found to be nonsignificant or negligibly negative for medium and small banks. Notably, this interaction effect is more substantial for large banks during the recent financial crisis, but the results remain steady only when unused commitments are included in the definition of lending.

These results suggest three important policy implications. First, policy actions such as capital injections and liquidity support to sustain bank lending are complementary and should be harmoniously implemented to be effective, particularly for large banks. Second, the results reinforce recent international regulatory reform efforts that emphasize the importance of both sufficient capital and liquidity management to mitigate the effects of external negative economic shocks on banks' intermediation capacity.[1] Finally, large banks behave differently from medium and small banks. This behavioral difference might support the idea that policy actions and regulations should be applied differently according to bank size.

This paper makes two contributions to the literature. First, it shows a significant interaction effect of bank capital and liquidity on credit supply for large banks. This effect suggests, furthermore, that bank capital and lending exhibit a complicated relationship rather than a linear relationship, which has in contrast been the focus in the literature. Second, the present study demonstrates that the role of unused commitments should be considered in analyzing the effect of bank capital on lending. This recommendation is consistent with Cornett et al. (2011), Ivashina and Scharfstein (2010), and Berger and Bouwman (2009).

The remainder of the paper is organized as follows. Section 2 presents a review of the literature, and Section 3 discusses our hypotheses. Section 4 briefly presents the data used and describes the empirical methodology and variables. Section 5 discusses the regression results, and Section 6 addresses robustness issues. Section 7 presents the study's conclusions and discusses the policy implications of the results.

2. Literature review

Many empirical studies have examined the effect of bank capital on lending, with most indicating a positive effect, albeit to various degrees. In an early study, Bernanke and Lown (1991) estimate that the effect of a 1-percentage-point increase in bank capital results in approximately 2–3 percentage point increases annually in loan growth.[2] Furlong (1992) and Hancock and Wilcox (1994) also suggest a positive effect of bank capital on lending. Furlong (1992) finds that the ratio of bank capital to target capital is positively associated with the growth of bank loans. Hancock and Wilcox's (1994) estimate shows that in 1991 in the US, a shortfall in each US$1 of bank capital resulted in a reduction of approximately US$4.50 in bank credit. In a recent study, Berrospide and Edge (2010) estimate an increase of approximately 0.7–1.2 percentage points in loan growth in response to a 1-percentage-point increase in bank capital ratio annually. Nonlinear and interaction effects with the output gap are also examined; however, none of these factors was found to be statistically significant.

The effect of an increase in capital ratio on loan growth estimated by Carlson et al. (2011) is less than that reported in previous studies. Based on annual US bank data from 2001 to 2009, the authors find that a 1-percentage-point increase in the capital ratio causes loan growth to increase approximately 0.05–0.2 percentage points annually. This positive relationship, however, was not observed prior to the recent financial crisis, in fact becoming significant only in 2008 and 2009. Thus, the researchers suggest that capital becomes more crucial for loan growth during the crisis period. This result corresponds to the results of Gambacorta and Marques-Ibanez (2011) and Cornett et al. (2011), although capital is not a focal point in these studies.

[1] BCBS (2011) emphasizes the importance of liquidity management because banks that do not effectively manage their liquidity suffered during the recent financial crisis despite possessing adequate capital.

[2] Although the authors conclude that bank capital and lending exhibit a lesser relationship than expected and that capital shortage is a minor factor in lending slowdown, their estimates are somewhat larger than those reported in related studies. Berrospide and Edge (2010) explain that the larger estimates by Bernanke and Lown (1991) can be attributed to their model's exclusion of other bank-specific control variables. In this model, then, the coefficient of capital ratio captures the effects of other variables.

The above-mentioned studies are based on US data, but Gambacorta and Mistrulli (2004) and Francis and Osborne (2012) focus on Italian and UK banks, respectively. Gambacorta and Mistrulli (2004) find that excess capital exerts a significantly positive effect on lending and that the effects of monetary policy and output shocks on bank lending differ depending upon the level of bank capitalization. Francis and Osborne (2012) show that banks increase their target capital ratios when capital requirements increase, and vice versa. Thus, banks increase their actual capital ratios following tightened capital requirements by adjusting their portfolios to favor less risky assets. This approach enables them to reduce the gap between internal target capital ratios and actual capital ratios, thus suggesting that bank lending is positively correlated with the gap between actual and target ratios.

Since the Basel Committee's adoption of the minimum capital requirement regulation in 1988, many studies have analyzed the ensuing effects on bank risk-taking behavior, lending, and the overall soundness and safety of individual banks and the banking system. More specifically, many researchers have examined whether capital requirements increase bank capital ratios and restrain bank risk-taking. These studies are closely related to the main issue addressed in the present study.

Van Hoose (2008) surveys previous academic research on this issue and concludes that no strong evidence exists concerning whether the contribution of stringent capital requirements significantly increases bank capital ratios. This finding is consistent with Jackson et al. (1999), who explored previous studies in the 1980s and 1990s to investigate whether banks increase capital ratios following regulatory capital requirements. The authors were unable to determine conclusively whether capital requirements cause banks to establish higher capital ratios than they otherwise would, although a broad consensus is that low-capital banks tend to increase their capital ratios more rapidly than do well-capitalized banks. Gropp and Heider (2009) also find that capital regulation is only a second-order determinant of banks' capital structures.

Jacques and Nigro (1997), however, find a contrasting result. They report that risk-based capital regulation increases capital ratios and decreases bank portfolio-related risks. Berger et al. (2008) also show that BHCs actively manage their capital ratios toward target capital ratios that are established substantially above the minimum capital requirements. In particular, they demonstrate that low-capital banks more quickly adjust their capital ratios toward target ratios than do well-capitalized banks. Considered together, the studies therefore provide mixed results.

A more important issue is related to the fact that considerable research investigates whether capital regulations contribute to credit shocks. Jackson et al. (1999) conclude that banks respond to tightened capital regulations in the least costly manner, therefore possibly causing these financial institutions to reduce lending in response to external shocks to capital. Such reduction is prompted by the fact that issuing new equity is costly and constrained during economic downturns. Van Hoose (2007) also argues that the theoretical literature reflects a general agreement that the short-run effects of capital regulation reduce loan supply. Furfine (2001) suggests that capital regulation constituted a key factor in the credit crunch of the 1990s because of its influence on the optimal portfolio allocation of banks. The results imply that actively managing capital ratios through adjustments in portfolio composition establishes a strong relationship between bank capital and lending.

3. Hypotheses

Most studies focus on the linear relationship between bank capital ratio and lending or examine whether a structural change occurs following external shocks. Brei et al. (2013) and Carlson et al. (2011), however, capture the nonlinear effects of a change in the capital ratio on loan growth.[3] The present study starts from the assumption that the effect of bank capital on lending might differ depending upon other bank-specific characteristics, given that this effect differs depending upon the level of the capital ratio itself. Among various bank-specific characteristics, liquidity level is examined for two reasons. First, the role of liquid assets on banks' credit supply capacity is established in other studies (see Cornett et al., 2011; Ivashina and Scharfstein, 2010; Berrospide, 2013). Second, the result can be used to speculate on the effectiveness of the Basel III regulation, which emphasizes the importance of high capital and liquidity asset management. Accordingly, we seek to test the following hypotheses.

Hypothesis 1. *The effect of bank capital on lending is positively associated with bank liquidity level.*

Hypothesis 2. *The positive relationship between the effect of bank capital on lending and bank liquidity level is stronger during the recent crisis.*

The hypotheses indicate that the effect of bank capital on lending exhibits an upward slope depending upon the liquidity level; in other words, we expect that banks with a greater value of liquid assets are expected to supply more lending following increases in capital than are banks with a lesser value of liquid assets. Until they acquire sufficient liquid assets, banks with a lesser value of liquid assets are likely to invest more resources in liquid assets than in supplying loans when capital increases. This prediction is consistent with other studies arguing that less liquid banks are likely to reduce loans to maintain their liquid asset holdings above a dangerously low level (Kashyap and Stein, 2000; Cornett et al., 2011; Berrospide, 2013). With respect to the second hypothesis, we test whether the results change during the crisis period. Acharya et al. (2011) argue that the level of bank liquidity is countercyclical, inefficiently low during economic booms and excessively high during crisis periods. Cornett et al. (2011) and Berrosopide (2013) also find that banks' efforts to increase liquidity buffers during the recent financial crisis reduced credit supply. We thus expect that the positive relationship between the effect of bank capital on lending and liquidity level is stronger during the recent crisis.

Our hypotheses also can be explained based on two strands of theories on the relationship between bank capital and liquidity creation,[4] the "financial fragility-crowding out" and the "risk absorption" theories, referred to by Berger and Bouwman (2009). The "financial fragility crowding out" hypothesis predicts that the effect of bank capital on lending is negative because, unlike depositors, capital investors who cannot run on the bank are reluctant to provide loans. Thus, banks with a higher capital ratio might supply fewer loans by crowding out deposits. Conversely, the effect of bank capital on lending is positive under the "risk absorption" theory because bank capital enhances banks' risk-bearing capacity.

[3] Brei et al. (2013) incorporate a quadratic term for the capital ratio in their equations to examine the nonlinear effect of a change in the capital ratio on loan growth. They find that an increase in the capital ratio positively affects loan growth and that this effect marginally decreases in normal situations but increases during crises. Carlson et al. (2011) also find a nonlinear effect on loan growth. They report that the effect is greater when the capital ratio is relatively low and closer to the regulatory minimum requirement.

[4] Liquidity creation here measures a bank's ability to transform liquid liabilities to illiquid assets; thus, these theories do not refer directly to the relationship between bank capital and lending. However, it is useful for understanding our hypotheses because liquidity creation indirectly measures a bank's capability to create loans, which are commonly considered the most illiquid assets. See Berger and Bouwman (2009) for a detailed discussion about the relationship between bank capital and bank liquidity creation.

Table 1
Number of commercial banks and sizes for each category by bank assets.

Panel A: as of 1992 Q4						
	<75%	75~90%	90~95%	95~98%	98~99%	≥99%
Number of banks	8597	1719	574	344	115	114
Mean assets (2009 $ millions)	62	233	532	1488	4563	23,245
Median assets (2009 $ millions)	53	219	508	1273	4346	13,051
Fraction of total assets (%)	10.8	8.1	6.2	10.4	10.7	53.8
Panel B: as of 2010 Q4						
	<75%	75~90%	90~95%	95~98%	98~99%	≥99%
Number of banks	4898	979	326	197	65	65
Mean assets (2009 $ millions)	119	470	1077	2633	8765	143,878
Median assets (2009 $ millions)	103	444	1044	2357	8632	49,070
Fraction of total assets (%)	4.9	3.9	3.0	4.4	4.8	79.0

Notes: This table lists the distribution of all commercial banks in 1992q4 and 2010q4 from the original data obtained from Federal Deposit Insurance Corporation Statistics on Depository Institutions (FDIC SDI) before applying any adjustments. Banks are categorized by total asset sizes in each period.

We expect that the "financial fragility-crowding out" effect dominates the "risk-absorption" effect when banks have insufficient liquid assets, and vice versa, because capital investors are likely to become more reluctant to provide loans when banks possess inadequate liquid assets and when an increase in bank capital alone cannot boost banks' risk-bearing capacity sufficiently. However, once banks accumulate sufficient liquid assets, it is likely that capital investors become less reluctant to supply loans, and the increase in bank capital improves banks' risk-absorbing capacity significantly.

Nonetheless, our expectation might prove contrary to existing research or inadequate. For example, the effect of bank capital on lending might be uncorrelated with the liquidity level if one of two theories dominates regardless of liquidity level. Moreover, the effect of bank capital on lending might decrease as the liquidity level increases, if the capital and liquidity ratio reflects only the business model or the equilibrium level of each bank. In such a scenario, banks with high liquidity ratios use capital to invest in liquid assets more so than do banks with low liquidity ratios, and vice versa. Thus, the effect of bank capital on lending can follow a downward slope, depending upon the liquidity ratio.[5]

4. Data and empirical methods

4.1. Data

This study uses quarterly observations of insured US commercial banks spanning the period from 1993 Q1 to 2010 Q4.[6] These data were obtained from the Federal Deposit Insurance Corporation Statistics on Depository Institutions (FDIC SDI), which provides detailed financial reports of FDIC-insured institutions in standardized formats. All balance sheet variables are deflated by implicit price deflator for GDP obtained from the US Bureau of Economic Analysis.

We divide our sample by bank size for two reasons. First, Table 1 indicates that our dataset features extremely skewed size distribution, i.e., numerous small banks with a minority of large banks. As of 2010 Q4, banks in the top 1 percent of the size distribution own 79 percent of total assets. In addition, figures of mean and median assets indicate that the size of each bank in the top 1 percent of the size distribution is dramatically larger than those of other individual banks. Second, the literature indicates different behaviors by bank size (see, e.g., Kashyap and Stein, 2000; Cornett et al., 2011; Berger and Bouwman, 2013). Fig. 2 also supports this view. The top 1 percent banks have significantly less liquid assets and regulatory capital than do the bottom 99 percent banks. In addition, the shrink of credit supply during the recent financial crisis is prominent for the top 1 percent banks. In this respect, we are concerned that regression results with the full sample could be dominated by the behavior of small banks, and understanding the behavior of the few large banks is critical.

For the reasons mentioned above, following the criteria used by Kashyap and Stein (2000), we divide our sample into three categories before applying any adjustments to the data: large banks are banks with total assets above the 99th percentile, medium banks are those with total assets from the 95th to 99th percentiles, and small banks include all other banks with total assets less than 95th percentile in each period. As a result, 6172 observations are initially categorized as large banks, 24,717 observations are categorized as medium banks, and 586,727 observations are categorized as small banks.

Then, adjustments are applied to mitigate the influence of missing or outlier values and possible mergers and acquisitions. First, all bank-specific variables except the size variable are winsorized at the 1st and 99th percentiles. Second, observations involving greater than 50% or less than −50% quarterly growth in assets are excluded to reduce a possibility of mergers and acquisitions. Finally, banks in violation of regulatory capital requirements during the examined period are excluded because institutions considered undercapitalized are constrained by various mandatory and discretionary supervisory actions, such as restrictions on asset growth and dividend payments. Thus, observations are excluded at a total risk-based capital ratio of less than 8%, at a tier 1 risk-based capital ratio of less than 4%, or at a leverage ratio less than 4%.

These adjustments leave us with a final sample of 521,376 observations: 3,849 observations for large banks, 18,632 observations for medium banks, and 498,895 observations for small banks. Concerning macroeconomic data, real GDP data are obtained from the US Bureau of Economic Analysis, and federal funds effective rates are obtained from the Federal Reserve Bank.

4.2. Econometric models

To validate our hypothesis concerning whether the relationship between bank capital and lending depends upon the liquidity level, a bank capital ratio variable is interacted with a bank liquidity ra-

[5] A downward slope can also be expected based on the "Warehouse banking theory" suggested by Donaldson et al. (2015) because liquidity and capital ratios exert opposite effects on liquidity creation according to their theoretical model. The theory stipulates that high liquidity requirements diminish banks' liquidity creation but that increasing bank capital boosts bank liquidity creation.

[6] The data are available from 1992 Q4, but we lose observations for 1992 Q4 because our regressions involve growth rates. Thus, our data for regressions span from 1993 Q1 to 2010 Q4.

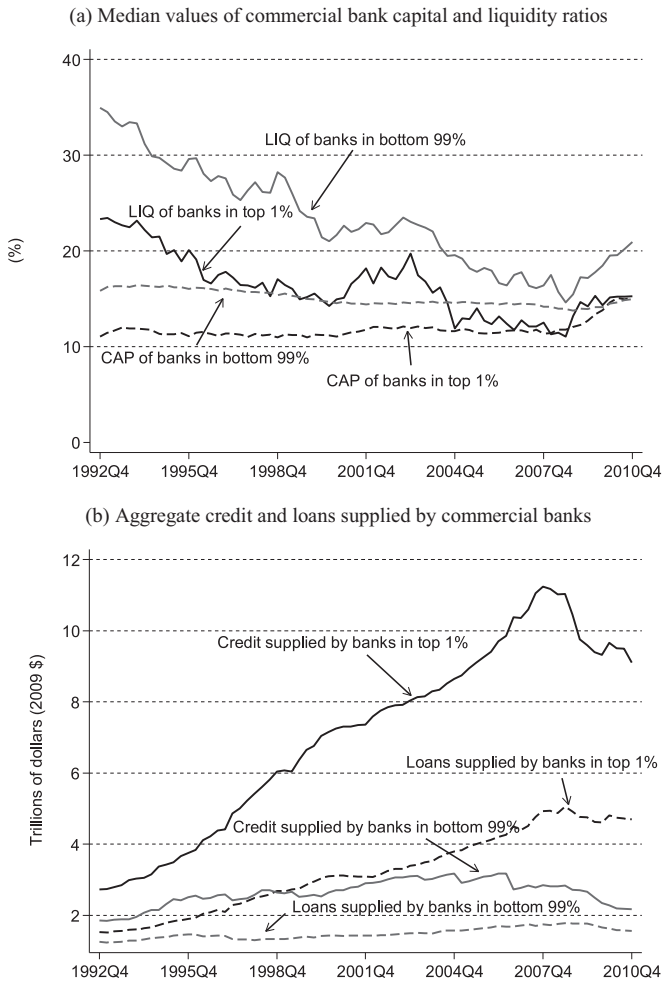

Fig. 2. Trends of bank capital, liquidity, and aggregate credit supply by bank size.
Notes: CAP is the total risk-based capital ratio. LIQ is the liquidity ratio, which is defined as the liquid assets share of total assets. Liquid assets comprise cash and the balance due from depository institutions plus securities, federal funds sold, and reverse repurchases, less pledged securities. Loans mean net loans. Credit equals sum of net loans and unused commitments. Banks are classified by asset size distribution in each quarter.
Source: Federal Deposit Insurance Corporation Statistics on Depository Institutions (FDIC SDI).

tio variable. This approach enables the coefficient of the bank capital ratio variable to fluctuate as the liquidity ratio changes. Specifically, the econometric model used by Brei et al. (2013) is employed with adjustments. For instance, a quadratic term of capital ratio is excluded; instead, an interaction term of capital ratio and liquidity ratio is used to verify the main hypothesis. Thus, the empirical model used in the present study is given by

$$L_{i,t} = \alpha_i + \beta_0 L_{i,t-1} + \beta_1 CAP_{i,t-1} + \beta_2 LIQ_{i,t-1} + \beta_3 CAP * LIQ_{i,t-1} + \gamma \mathrm{X}_{i,t-1} + \delta_1 \Delta GDP_{t-1} + \delta_2 \Delta MP_{t-1} + \sum_{j=1994}^{2010} \theta_j \mathrm{Y}_j + \sum_{s=2}^{4} \varphi_s \mathrm{Q}_s + \varepsilon_{i,t}, \quad (1)$$

where i denotes the number of banks, and t represents the quarterly time dimension.

In these econometric models, each coefficient captures the short-term effect on lending in response to a change in the variable. In contrast, the long-term influence is expressed by dividing each coefficient by $(1-\beta_0)$. For example, $\Delta L_{i,t}/\Delta \mathbf{X}_{i,t-1} = \gamma/(1-\beta_0)$ indicates the long-term effect on loan growth rate in response to a change in the variable in vector X.

The dependent variable ($L_{i,t}$) is the quarterly growth rate of lending of bank i in period t. Following the convention adopted by most studies (e.g., Kashyap and Stein, 1995; Gambacorta and Mistrulli, 2004; Berrospide and Edge, 2010; Drehmann and Gambacorta, 2012; Brei et al., 2013; Kapan and Minoiu, 2013), we use the growth rate of the dependent variable instead of the variable in levels to mitigate spurious correlation.

We employ two types of the dependent variable: the quarterly growth rate of net loans and unused commitments ($CREDIT_t$) and the quarterly growth rate of net loans ($LOAN_t$). As Cornett et al. (2011) and Ivashina and Scharfstein (2010) highlight, the drawdowns of unused commitments that are not caused by the expiration of the term do not affect the total credit amount because the same amount of loans increases. Hence, credit lines opened before the crisis are useful for borrowers, who can employ unused commitments when banks are reluctant to lend. Thus, an increase in loans caused by the drawdowns of unused commitments is likely to affect bank lending behavior and the relationship between bank capital and lending. Given this likely effect of drawdowns, we prefer the credit growth variable as a dependent variable.

Our main interest is the coefficient (β_3) on the interaction term of bank capital and liquidity ratios ($CAP * LIQ_{i,t-1}$). Because we expect that the effect of bank capital on lending is positively associated with the liquidity level, the expected sign is positive.

Bank-specific characteristic variables and macroeconomic control variables are included as explanatory variables. The bank-specific variables used by Brei et al. (2013) are all included, except the square term of the regulatory capital ratio.[7] With these variables, we use the additional bank-specific characteristic variables that are considered in the literature as important control variables that affect bank lending.[8]

Bank-specific characteristics, except the capital ratio and the liquidity ratio, are included in the vector $\mathbf{X}_{i,\,t-1}$. All bank-specific characteristic variables, except the capital ratio, are normalized to their mean values in each size category. The capital ratio is normalized to the minimum regulatory requirements, 8%. Normalization enables the generation of meaningful coefficients. The procedure involves interpreting the coefficients of the capital ratio as the effects on banks with an average liquidity ratio and interpreting the coefficients of liquidity ratio as the effects on banks with minimum regulatory capital ratios.

In addition, a quarterly growth rate of real GDP (ΔGDP_{t-1}) and a change in the federal funds effective rate (ΔMP_{t-1}) are included to account for the effects of macroeconomic conditions and loan demands. α_i represents bank-level fixed effects that capture unobserved bank characteristics. Yearly dummies ($\mathrm{Y_j}$) and quarterly dummies ($\mathrm{Q_s}$) are also included in all regressions to capture business cycle conditions and control for seasonal influences. All bank-specific variables and macroeconomic control variables are lagged one period to mitigate any possible endogeneity bias. Table 2 presents definitions and summary statistics of the variables used in the regressions. Descriptions and expected signs of the variables are as follows.

***Capital* (CAP_{t-1})**: The total risk-based capital ratio is primarily considered in this study.[9] According to the literature, the coeffi-

[7] These variables are the bank regulatory capital ratio ($CAP_{i,t-1}$), the bank liquidity ratio ($LIQ_{i,t-1}$), the market funding ratio ($MFUND_{i,t-1}$) and the log of total assets ($SIZE_{i,t-1}$).

[8] According to Cornett et al. (2011), the ratio of unused commitments ($COMMIT_{i,t-1}$) is included because unused commitments are important explanatory variables that influence bank lending by exposing banks to liquidity risk. The ratio of return on total assets (ROA_{t-1}) is used as a bank profitability proxy, and the ratio of noncurrent loans to total loans (NPL_{t-1}) and the ratio of loan loss allowance to loans ($ALLOW_{t-1}$) are used as indicators of bank asset quality.

[9] There are three regulatory capital ratios: the total risk-based capital ratio, the tier 1 risk-based capital ratio, and the leverage ratio. The total risk-based capital

Table 2
Definition of variables and summary statistics by bank size.

Variable		Large (≥99%)		Medium (95∼99%)		Small (<95%)	
		Mean	Std	Mean	Std	Mean	Std
Dependent variables (L_t)							
$CREDIT_t$	Quarterly real growth rate of net loans and unused commitments (%)	1.94	5.98	2.01	5.64	2.02	5.89
$LOAN_t$	Quarterly real growth rate of net loans (%)	1.85	6.59	1.92	5.71	1.97	6.02
Bank-specific characteristic variables							
CAP_{t-1}	Total risk-based ratio (%)	12.00	2.48	12.94	3.45	17.43	7.51
LIQ_{t-1}	Ratio of liquid assets to total assets (%)	19.88	12.74	19.01	12.06	26.33	14.14
$SIZE_{t-1}$	Logarithm of total assets	17.26	1.01	14.72	0.63	11.50	0.98
$MFUND_{t-1}$	Ratio of non-deposit liabilities to total assets (%)	20.25	8.75	12.78	8.24	4.53	5.34
$COMMIT_{t-1}$	Ratio of unused commitments to total assets (%)	31.58	14.14	18.44	10.50	8.85	6.94
ROA_{t-1}	Return on total assets (%)	1.09	0.67	1.12	0.77	1.07	0.78
NPL_{t-1}	Noncurrent loans to loans (%)	1.29	1.32	1.17	1.39	1.12	1.41
$ALLOW_{t-1}$	Loan loss allowance to loans (%)	1.77	0.82	1.63	0.71	1.50	0.67
Macroeconomic controls							
$\triangle GDP_{t-1}$	Quarterly growth rate of real GDP (%)	0.64	0.67				
$\triangle MP_{t-1}$	Change in federal funds effective rate (%)	−0.04	0.48				
C	Dummy, 1 for the period from 2007 Q3 to 2009 Q2						
No. of observations		3,849		18,632		498,895	

Notes: This table reports the summary statistics of the variables used in the regressions. All balance sheet variables, real GDP, and federal funds rate are obtained from Federal Deposit Insurance Corporation Statistics on Depository Institutions, the US Bureau of Economic Analysis, and the Federal Reserve Bank H.15, respectively. The sample period spans 1993 Q1 to 2010 Q4 because we lose observations in 1992 Q4 to calculate growth rates. All balance sheet variables are deflated by an implicit price deflator for GDP obtained from the US Bureau of Economic Analysis. Thus, $CREDIT_t$ and $LOAN_t$ are the quarterly real growth rates, calculated as $100 \times (\ln(L_t) - \ln(L_{t-1}))$. CAP_{t-1} is the lagged total risk-based capital ratio. LIQ_{t-1} is the lagged liquidity ratio, which is defined as the liquid assets share of total assets. Liquid assets comprise cash and the balance due from depository institutions plus securities, federal funds sold, and reverse repurchases, less pledged securities. $SIZE_{t-1}$ is measured by the logarithm of lagged total assets. Market funding ($MFUND_{t-1}$) is the lagged ratio of non-deposit liabilities to total assets. $COMMIT_{t-1}$ is the lagged ratio of unused commitments to total assets. ROA_{t-1} is the lagged return on total assets. NPL_{t-1} is the lagged ratio of noncurrent loans to total loans, and $ALLOW_{t-1}$ is the lagged ratio of loan loss allowance to loans. For the macroeconomic controls, the quarterly growth rate of real GDP (ΔGDP_{t-1}) and a change in the federal funds effective rate (ΔMP_{t-1}) are used. These macroeconomic variables are also lagged by one quarter. C is a crisis dummy equal to 1 for the period 2007 Q3–2009 Q2, and 0 otherwise.

cients of the capital ratio are expected to be positive because well-capitalized banks can more effectively absorb the negative effects of shocks on bank lending (see, e.g., Bernanke and Lown, 1991; Furlong, 1992; Hancock and Wilcox, 1994; Gambacorta and Mistrulli, 2004; Meh and Moran, 2010; Berrospide and Edge, 2010; Carlson et al., 2011; Francis and Osborne, 2012; Kapan and Minoiu, 2013).

Liquidity (LIQ_{t-1}): Cash and securities are generally considered liquid assets, although researchers adjust definitions based on the availability of specific information and their evaluations.[10] This paper employs the definition used by Shim (2013). We determine liquid assets by summing cash and balances due from depository institutions, securities, federal funds, and trading account assets and then subtracting pledged securities. Concerning only the assets that are pledgeable and available for sales as liquid assets is a rational approach. The coefficients of the liquidity ratio are expected to be positive for the reasons discussed in Section 3.

Bank size ($SIZE_{t-1}$): Bank size is calculated as the natural logarithm of total assets. The expected sign of this variable is ambiguous. According to the "too big to fail" theory, large banks have incentives to take more risk amid high expectations of government bailout to prevent systemic risk, thereby enabling the supplying of more credit. However, large banks can diversify their portfolio by investing in various types of securities and involving themselves in various activities, whereas small banks tend to pursue traditional lending activities. From this perspective, the size effect can be negative.

Funding structure ($MFUND_{t-1}$): This variable is calculated as the ratio of total liabilities minus total deposits to total assets. The expected sign of coefficients of this variable is positive for large banks and negative for small banks. This expectation is adopted because large banks can more strongly rely on market funding to expand their balance sheets; such funding is typically considered more cost-effective and easier for them to accumulate. However, small banks that have less access to market funding are more likely to depend upon deposits to expand their balance sheets.

Unused commitments ($COMMIT_{t-1}$): Cornett et al. (2011) and Ivashina and Scharfstein (2010) show that this variable, which is the ratio of unused commitments to total assets, is an important determinant of bank lending behavior. Notably, the expected sign of this variable depends upon the type of dependent variable. The expected sign is positive for the growth rate of loans, but negative for the growth rate of credit because the drawdowns of unused commitments increase loans without affecting the credit amount. For this reason, banks exposed to a higher level of unused commitments more unwillingly supply loans, given that the increased credit line drawdowns can transfer assets from off balance sheets to on balance sheets. Consequently, these banks reduce the supply of new credit to a greater extent than do other banks.

Profitability (ROA_{t-1}): Profitability is measured as the ratio of net income after taxes and extraordinary items to total assets. Banks with high profitability are likely to have strong balance sheets because profitability is related to the quality and quantity of capital ratios. Thus, a positive relationship between profitability and bank lending is expected. In contrast, a higher profitability can imply a greater risk on assets. In this respect, banks with a high profitability might supply fewer loans to improve the quality of assets. Under this scenario, a relationship between profitability and bank lending can be negative.

ratio is determined as core capital (tier 1) plus supplementary capital (tier 2) over risk-weighted assets; this ratio should be at least 8% for banks to be deemed adequately capitalized. The tier 1 risk-based capital ratio includes only core capital in the numerator, which is divided by risk-weighted assets; this ratio should be at least 4%. Finally, the leverage ratio is calculated by dividing core capital (tier 1) by total average assets rather than risk-weighted assets. Two other regulatory capital ratios are used later for robustness checks.

[10] For example, Berrospide and Edge (2010) uses a securities-over-assets ratio as a proxy for liquidity ratio, whereas Drehmann and Gambacorta (2012) and Gambacorta and Mistrulli (2004) classify cash and securities as liquid assets. Brei et al. (2013) designate cash, trading securities, and interbank lending with a maturity of less than 3 months as liquid assets.

Loan quality (NPL_{t-1} and $ALLOW_{t-1}$): The ratio of noncurrent loans to total loans reflects the quality of the bank loan portfolio. While this ratio is a backward-looking measure of loan quality, the ratio of loan loss allowance to loans is considered a forward-looking measure. Thus, both variables are included. The higher the level of the variable is, the worse the portfolio quality is. Banks reduce lending by more-substantial degrees as loan quality worsens. Thus, the expected signs on these variables are negative.

Macroeconomic variables: To incorporate the effects of business cycle and monetary policy, a growth rate of real GDP (ΔGDP_{t-1}) and changes in the federal funds effective rate (ΔMP_{t-1}) are used. The expected sign of the growth rate of real GDP is positive because of the inherent procyclicality of bank lending and increased loan demands. Alternatively, the effect of changes in interest rate on bank lending is expected to be negative because increases in market rates decrease loan demands.

Crisis dummy ($CRISIS_t$): To determine whether a structural change occurs because of external economic shocks, the crisis dummy is interacted with bank-specific characteristic variables. The crisis dummy is an indicator variable that assumes a value of 1 for the period spanning 2007 Q3 to 2009 Q2, which is considered the most severe crisis period (see Cornett et al., 2011), and 0 otherwise.[11]

This study employs only the fixed effects panel method, although Brei et al. (2013) employ a dynamic system Generalized Method of Moments (GMM) panel methodology developed by Blundell and Bond (1998) to ensure efficiency and consistency. Brei et al. (2013) and Gambacorta and Mistrulli (2004) argue that this methodology ensures efficiency and consistency as long as the models do not suffer from serial correlation of order two and valid instruments are used. However, Roodman (2006) recommends fixed effects estimators as superior alternatives to GMM for the case of a large time dimension T because in such cases, the dynamic panel bias becomes insignificant, and the number of instruments tends to increase considerably as T increases. Furthermore, Judson and Owen (1999) suggest that fixed effects estimators perform well or better when the time dimension of panel data T is greater than 30. Because the time dimension of datasets is 71 for most regressions, and the minimum time dimension is 62, we adopt the bank fixed effects panel model. The fixed effects method has been extensively used in the literature (see, e.g., Berrospide and Edge, 2010; Francis and Osborne, 2012; Cornett et al., 2011). Conversely, fixed effects are selected in favor of random effects based on the unreported Hausman test results. As argued by Brei et al. (2013), nonrandomly selecting a sample from the population of banks is also consistent with the choice of fixed effects estimations.

5. Empirical results

5.1. Linear regression results

Before discussing the main regression results, we present the baseline regressions, which examine the linear relationship between bank lending and bank-specific characteristic variables without including the interaction terms of the capital ratio and the liquidity ratio. Table 3 reports the linear regression results.

First, the estimated coefficients of the capital ratio are different by bank size: the coefficients are positive but statistically nonsignificant for large banks; the coefficients are positive but only significant when loan growth is used as the dependent variable for medium banks; and the coefficients are positive and statistically significant for small banks. In terms of the magnitude of coefficients, the results in Specifications (5) and (6) suggest that a 1-percentage-point increase in the capital ratio for small banks is associated with approximately 0.4–0.5 percentage point increases in annualized loan growth rate and annualized credit growth rate.[12] Notably, for large and medium banks, the association between capital ratio and credit growth is smaller and statistically less significant than that between capital ratio and loan growth. These results imply that those banks are less constrained by the regulatory capital ratio when they expand their credit by supplying credit lines to customers. This relaxed relationship can be attributed to the lower risk-weights for off balance sheet activities compared with on balance sheet activities.

In all regressions, the coefficients of all of the other control variables are generally significant, with expected signs. Concerning the coefficients of the liquidity ratio, the estimated coefficients are positive and statistically significant for all three groups as expected. The size effect is negative, implying that small banks focus on traditional lending activity and therefore supply lending relatively more willingly than do large banks. The market funding effect is significantly positive for large and medium banks but somewhat negative for small banks, suggesting that large US commercial banks rely on market funding during the examined period to boost their lending. The results also reflect the importance of the unused commitment ratio on loan growth. As previously discussed, changes in unused commitments positively affect loan growth but negatively influence credit growth. The magnitude of coefficients is considerable and highly statistically significant, indicating that lending by banks more exposed to credit line risk increases through credit line drawdowns. These banks reduce the supply of new loans or credit lines following increased takedown demands. Unused commitments therefore exert contrasting effects on loan growth and credit growth. The coefficients of profitability (ROA_{t-1}) are positive for large and medium banks but negative for small banks. The coefficients of the loan quality variables (NPL_{t-1} and $ALLOW_{t-1}$) are negative and consistent in all regressions. As expected, the low quality of loans deteriorates banks' ability to supply loans.

Finally, macroeconomic variables are used with yearly time dummies to incorporate the effects of business cycle and monetary policy. The coefficients of GDP growth are generally positive, but magnitudes and statistical significance are greater for large banks. For small banks, the coefficients are small and even slightly negative when the growth rate of loans is used as the dependent variable. These findings suggest that over a business cycle, large banks are more procyclical compared with small banks. Concerning the coefficients of changes in the federal funds effective rate, the estimated coefficients are positive for all groups; the results are inconsistent with our expectation. This result might reflect the fact that monetary policy is procyclical; interest rates increase during the boom period but decrease in response to external economic shocks.

5.2. Interaction effect of bank capital and liquidity ratios on lending

In the regression models with an interaction term, the coefficients of capital ratio and liquidity ratio reflect the conditional effects of these variables on loan growth and credit growth. The liquidity ratio is normalized to its mean value in each bank size category; therefore, the coefficients of capital ratio are interpreted as the effect of capital ratio on loan and credit growth for banks with

[11] It is difficult to specify the crisis period. It is commonly defined as beginning at 2007 Q3, but its ending period is debatable. Consequently, we employ an alternative definition of the crisis period, defined as the period between 2007 Q3 and 2010 Q4 for robustness check in later.

[12] The annualized short-term effect approximates $\beta_1 \times 4$, and the annualized long-term effect approximates $\beta_1/(1-\beta_0) \times 4$.

Table 3
Base regressions.

Definition of L	Large banks (≥99%)		Medium banks (95~99%)		Small banks (<95%)	
	CREDIT (1)	LOAN (2)	CREDIT (3)	LOAN (4)	CREDIT (5)	LOAN (6)
L_{t-1}	0.003	0.024	0.039***	0.050***	0.136***	0.146***
	(0.028)	(0.026)	(0.010)	(0.010)	(0.003)	(0.003)
CAP_{t-1}	0.009	0.047	0.052	0.082**	0.096***	0.099***
	(0.116)	(0.123)	(0.032)	(0.034)	(0.005)	(0.005)
LIQ_{t-1}	0.103***	0.153***	0.030***	0.050***	0.061***	0.098***
	(0.029)	(0.032)	(0.010)	(0.010)	(0.002)	(0.002)
$SIZE_{t-1}$	−0.513	−1.312**	−3.261***	−3.380***	−1.529***	−1.512***
	(0.550)	(0.565)	(0.324)	(0.324)	(0.071)	(0.063)
$MFUND_{t-1}$	0.066**	0.051*	0.036***	0.058***	−0.020***	−0.012***
	(0.026)	(0.026)	(0.012)	(0.011)	(0.003)	(0.004)
$COMMIT_{t-1}$	−0.041**	0.050**	−0.055***	0.087***	−0.083***	0.278***
	(0.019)	(0.021)	(0.011)	(0.013)	(0.004)	(0.006)
ROA_{t-1}	0.797***	0.872***	0.763***	0.678***	−0.633***	−0.709***
	(0.249)	(0.246)	(0.091)	(0.092)	(0.025)	(0.025)
NPL_{t-1}	−0.288	−0.239	−0.531***	−0.471***	−0.542***	−0.414***
	(0.189)	(0.216)	(0.073)	(0.074)	(0.010)	(0.010)
$ALLOW_{t-1}$	−0.356	−0.429	−0.097	0.029	−0.580***	−0.415***
	(0.317)	(0.389)	(0.135)	(0.142)	(0.029)	(0.029)
$\triangle GDP_{t-1}$	0.405**	0.572***	0.174**	0.072	0.069***	−0.033**
	(0.194)	(0.213)	(0.085)	(0.084)	(0.016)	(0.016)
$\triangle MP_{t-1}$	0.351	0.413	0.174	0.482***	0.082***	0.269***
	(0.310)	(0.341)	(0.133)	(0.134)	(0.024)	(0.023)
Observations	3,849	3,849	18,632	18,632	498,895	498,895
Adjusted R^2	0.089	0.073	0.108	0.109	0.126	0.183

Notes: This table reports fixed effects regression results, which examine the linear relationship between bank lending and bank-specific characteristic variables without including the interaction terms of the capital ratio and the liquidity ratio. The sample period extends from 1993 Q1 to 2010 Q4. For the dependent variable, quarterly real growth rates of net loans and unused commitments ($CREDIT_t$) are used in Eqs. (1), (3), and (5), whereas quarterly real growth rates of net loans ($LOAN_t$) are used in Eqs. (2), (4), and (6). Large banks are banks with total assets above the 99th percentile, medium banks are those with total assets from the 95th to 99th percentiles, and small banks include all other banks with total assets less than the 95th percentile in each period. The capital ratios (CAP_{t-1}) are normalized to the minimum regulatory requirement, 8%. All other bank-specific characteristic variables are normalized to their mean values by each size category. All regressions include yearly dummies and quarterly dummies to capture business cycle conditions and control for seasonal influences. Constant terms are included but not reported. Robust standard errors, clustered at the bank level, are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

an average liquidity ratio in each category. In an identical manner, the coefficients of the liquidity ratio pertain to the effect of the liquidity ratio on loan and credit growth for banks with a minimum regulatory capital requirement, given that capital ratio is normalized to its minimum regulatory requirement.

Panel A in Table 4 presents the interaction effects of capital and liquidity ratio on credit growth; Panel B in Table 4 reports the interaction effects of capital and liquidity ratio on loan growth.[13] In specifications (2), (4), and (6), the crisis dummy is interacted with all bank-specific characteristic variables, including interaction term, to examine whether a structural change occurs following external shocks.

Because our regression results differ by the type of the dependent variable, we initially interpret the results for credit growth (see Panel A in Table 4). First, we can observe that the results differ by bank size, and our hypothesis—the effect of bank capital on lending is positively associated with the liquidity level—is confirmed only for large banks. A standard deviation increase in liquidity ratio for large banks elevates the effects of a 1-percentage-point increase in the capital ratio on credit growth by approximately 0.13 percentage points in a quarter.[14] This finding suggests that the effect of an increase in capital ratio on credit growth is significantly negative for low liquidity ratios, becoming significantly positive only after large banks retain sufficient liquid assets. This interaction effect is found to be nonsignificant or negligibly negative for medium and small banks. Fig. 3 illustrates how the interaction effects of the capital ratio and the liquidity ratio on credit growth differ by bank size. These interaction effects are negligible, however, for the effects of the liquidity ratio on credit growth, given the relatively low volatility of capital ratios.[15]

The fact that the interaction effects are notable for large banks implies that such banks more actively and simultaneously manage their capital ratios and liquidity ratios. This implication follows from noticing that large banks tend to maintain lower capital ratios and liquidity ratios than do medium and small banks. This strategy makes large banks more sensitive to changes in capital and liquidity ratios.

Furthermore, the coefficient of the interaction term with crisis dummy is significantly positive and prominent for large banks when credit growth is used as the dependent variable, thereby suggesting that the positive relationship between the effect of bank capital on lending and the liquidity level is stronger during the recent financial crisis. This relationship is illustrated in Fig. 4. Notably, the upward shape, which shows that the effect of bank capital on credit growth depends upon the level of the liquidity ratio, is pronounced during the crisis period.

The results suggest that following external economic shocks, large banks with sufficient liquid assets can supply more credit with capital than can banks with insufficient liquid assets. This

[13] For simplicity, we report only central coefficients hereafter.

[14] 0.13 = 0.010*12.74(standard deviation of LIQ variable for large banks).

[15] A standard deviation increase in capital ratio for large banks elevates the effects of a 1-percentage-point increase in liquidity ratio on credit growth by only approximately 0.02 percentage points(=0.010*2.48) in a quarter.

Table 4
Interaction effect of capital and liquidity on credit growth and loan growth.

	Large banks (≥99%)		Medium banks (95~99%)		Small banks (<95%)	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: L = CREDIT						
CAP_{t-1}	−0.154	−0.119	0.034	0.030	0.117***	0.110***
	(0.108)	(0.112)	(0.039)	(0.040)	(0.006)	(0.006)
CAP_{t-1}*C		−0.268		0.003		0.058***
		(0.208)		(0.065)		(0.008)
LIQ_{t-1}	0.058**	0.078**	0.023*	0.023*	0.072***	0.071***
	(0.029)	(0.031)	(0.013)	(0.013)	(0.002)	(0.002)
LIQ_{t-1}*C		−0.149***		0.032		−0.001
		(0.057)		(0.035)		(0.004)
CAP_{t-1}*LIQ_{t-1}	0.010***	0.009***	0.001	0.001	−0.001***	−0.001***
	(0.003)	(0.003)	(0.001)	(0.001)	(0.000)	(0.000)
CAP_{t-1}*LIQ_{t-1}*C		0.018**		−0.004		−0.001**
		(0.008)		(0.006)		(0.000)
Observations	3,849	3,849	18,632	18,632	498,895	498,895
Adjusted R^2	0.093	0.096	0.108	0.109	0.126	0.127
Panel B: L = LOAN						
CAP_{t-1}	−0.143	−0.103	0.058	0.054	0.128***	0.123***
	(0.140)	(0.143)	(0.039)	(0.039)	(0.006)	(0.006)
CAP_{t-1}*C		−0.157		0.002		0.040***
		(0.164)		(0.058)		(0.007)
LIQ_{t-1}	0.099***	0.120***	0.040***	0.040***	0.114***	0.114***
	(0.034)	(0.037)	(0.013)	(0.014)	(0.003)	(0.003)
LIQ_{t-1}*C		−0.107**		0.026		−0.008*
		(0.046)		(0.038)		(0.005)
CAP_{t-1}*LIQ_{t-1}	0.012***	0.010***	0.002	0.002	−0.002***	−0.002***
	(0.003)	(0.004)	(0.001)	(0.002)	(0.000)	(0.000)
CAP_{t-1}*LIQ_{t-1}*C		0.007		−0.003		0.000
		(0.006)		(0.006)		(0.000)
Observations	3,849	3,849	18,632	18,632	498,895	498,895
Adjusted R^2	0.076	0.080	0.109	0.110	0.184	0.184

Notes: This table summarizes the coefficients related to the capital ratio (CAP_{t-1}) and liquidity ratio (LIQ_{t-1}) variables from the fixed effects regression results. All other bank-specific characteristic variables and macroeconomic control variables are included, but the coefficients are not reported because of space limitations. The sample period extends from1993 Q1 to 2010 Q4. The crisis dummy assumes a value of 1 for the period from 2007 Q3 to 2009 Q2. For the dependent variable, quarterly real growth rates of net loans and unused commitments ($CREDIT_t$) are used in Panel A, whereas quarterly real growth rates of net loans ($LOAN_t$) are used in Panel B. Large banks are banks with total assets above the 99th percentile, medium banks are those with total assets from the 95th to 99th percentiles, and small banks include all other banks with total assets less than the 95th percentile in each period. Capital ratios (CAP_{t-1}) are normalized to minimum regulatory requirements, 8%. Liquidity ratios are normalized to mean values by each size category. All regressions include yearly dummies and quarterly dummies to capture business cycle conditions and control for seasonal influences. Constant terms are included, but not reported. Robust standard errors, clustered at the bank level, are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

finding is consistent with those of Cornett et al. (2011) and Berrosopide (2013). Our finding—the effect of bank capital on credit growth is negative at low liquidity levels—suggests that large banks' efforts to increase liquidity buffers during the crisis inhibit credit supply.

However, although similar regression results are generally obtained when loan growth is employed as the dependent variable (see Panel A in Table 4), the coefficient of the interaction term with crisis dummy for large banks is smaller and statistically nonsignificant. Thus, our result for the crisis period is confirmed only when unused commitments are considered. The fact that the regression results differ by the type of the dependent variable for large banks during the recent crisis highlights the important role of unused commitments. Although average net loan to asset ratios are relatively comparable by bank size, the average credit to asset ratio of large banks is considerably higher than are those of medium and small banks.[16] In this respect, the result also implies that large banks exposed more to off balance sheet liquidity risk stemming from unused commitments might seek to accumulate liquid assets rather than supply credit until their liquidity ratio reaches a certain level.[17]

6. Robustness checks

In this section, we conduct several robustness checks to determine whether our results remain unchanged. First, we investigate the robustness of our results by employing two alternative measures for liquid assets. To address the data limitation, two alternative measures for bank liquidity are employed: (i) liquid assets equaling the sum of cash and the balance due from depository institutions, US government securities, and federal funds sold and reverse repurchases and (ii) liquid assets equaling the sum of cash and the balance due from depository institutions, available-for-sale securities, and federal funds sold and reverse repurchases.[18]

[16] In our sample, average net loan to asset ratios are comparable by bank size: 62% for large banks, 63% for medium banks, and 60% for small banks. In contrast, average credit-to-asset ratios differ noticeably by bank size: 94% for large banks, 82% for medium banks, and 69% for small banks.

[17] Our findings are similar to those of Berger and Bouwman (2009), who find that the effect of bank capital on liquidity creation is positive and significant only for large banks and highlight the importance of off balance sheet activities (most of which are unused commitments) for such results. This view is also consistent with Distinguin et al. (2013).

[18] These two alternative definitions are consistent with Cornett et al. (2011), who argue that the markets of some types of securities such as mortgage-backed secu-

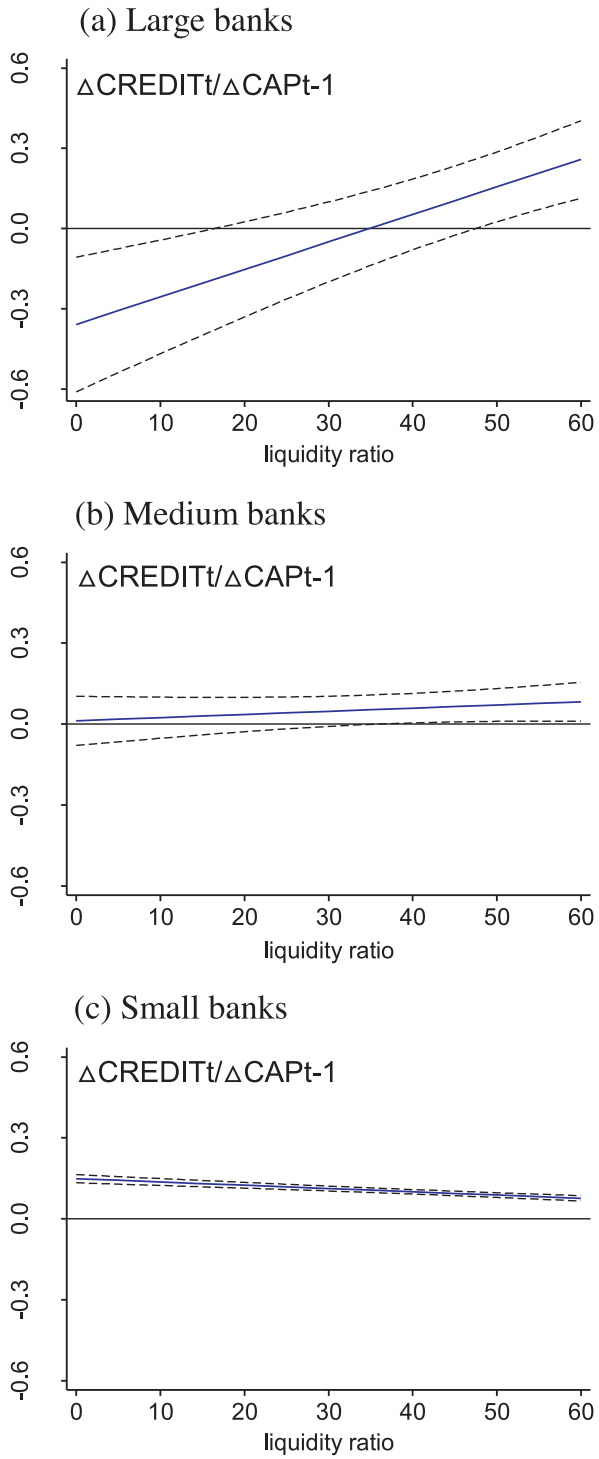

Fig. 3. The effects of a change in capital ratio on credit growth by bank size.
Notes: The vertical axes represent the derivative $\Delta CREDIT_{ijt}/\Delta CAP_{ijt-1}$. Coefficients are drawn from Specifications (1), (3), and (5) in Table 4, respectively. The dashed lines indicate the 10% and 90% confidence intervals, calculated with the delta method.

Specifications (1) and (2) in Table 5 show that the regression results remain unchanged.

rities and asset-backed securities disappeared at the beginning of the recent crisis. For this reason, they define cash, federal funds sold, US government securities, and securities purchased under agreement to resell as liquid assets. Due to data limitations, we cannot exclude pledged assets.

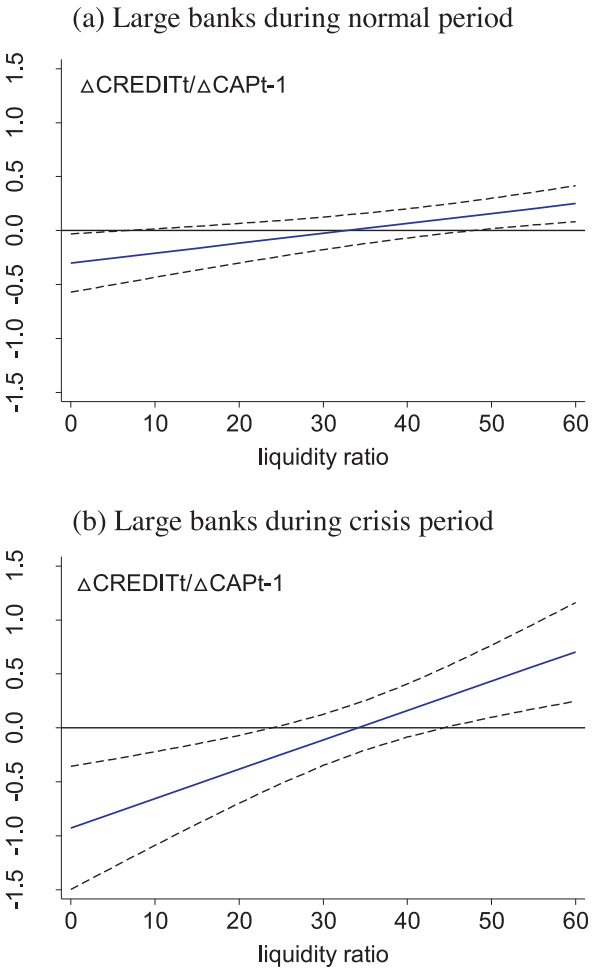

Fig. 4. The effects of a change in capital ratio on credit growth for large banks.
Notes: The vertical axes represent the derivative $\Delta CREDIT_{ijt}/\Delta CAP_{ijt-1}$. Coefficients are drawn from Specification (2) in Table 4. The dashed lines indicate the 10% and 90% confidence intervals, calculated with the delta method.

Second, we perform regressions with an alternative measure for the crisis dummy. It is difficult to specify the crisis period; it is commonly defined as beginning at 2007 Q3, but its ending period is debatable. For this reason, we employ an alternative definition of the crisis period, defined as the period between 2007 Q3 and 2010 Q4. The results are shown in specification (3) in Table 5. Although the coefficient of the interaction term with the crisis dummy is statistically nonsignificant as we expand the crisis definition, it is positive as expected.

Third, with respect to the estimation period, including the Troubled Asset Relief Program (TARP) implementation period can distort results. TARP was one of the major programs implemented by the US Department of the Treasury following the recent financial crisis in an effort to stabilize the financial system. The program was initiated on October 28, 2008, when the Treasury injected capital into the nine largest banks under the Capital Purchase Program (CPP) (Black and Hazelwood, 2012).[19] Therefore, the period that excludes the time after the implementation of TARP capital injections

[19] Black and Hazelwood (2012) and Berrospide and Edge (2010) state that one of the objectives of the CPP is to increase bank lending by injecting capital through purchases of preferred stock with warrants. Consequently, the capital ratios of US banks significantly increase after 2008 Q4. Thus, Berrospide and Edge (2010) adopt the period before 2008 Q4 as the cutoff for the estimation period, which marked the beginning of the TARP capital injections; the authors use this strategy to prevent distortions in the regression results. Black and Hazelwood (2012) argue that the bank recipients of TARP funds are encouraged to increase loans.

Table 5
Robustness checks.

L = CREDIT	Alternative measures for liquidity		CRISIS (07q3∼10q4)	Pre-TARP Period	Alternative criteria for bank size
	LIQ1	LIQ2			
	(1)	(2)	(3)	(4)	(5)
Panel A: Large banks (≥99%)					*(≥98%)*
CAP_{t-1}	−0.065	−0.141	−0.165	−0.169	0.015
	(0.126)	(0.126)	(0.134)	(0.137)	(0.059)
CAP_{t-1}*C	−0.486*	−0.441	0.078	−0.079	−0.237**
	(0.285)	(0.276)	(0.163)	(0.237)	(0.115)
LIQ_{t-1}	0.060*	0.051	0.077**	0.073**	0.036
	(0.033)	(0.034)	(0.031)	(0.032)	(0.022)
LIQ_{t-1}*C	−0.127**	−0.133**	−0.133***	−0.143**	−0.077**
	(0.058)	(0.064)	(0.049)	(0.065)	(0.033)
CAP_{t-1}*LIQ_{t-1}	0.008	0.008	0.011***	0.012***	0.003
	(0.005)	(0.005)	(0.003)	(0.003)	(0.003)
CAP_{t-1}*LIQ_{t-1}*C	0.031**	0.026*	0.005	0.016*	0.011**
	(0.015)	(0.015)	(0.005)	(0.009)	(0.005)
Observations	3,849	3,590	3,849	3,505	8,051
Adjusted R^2	0.089	0.093	0.098	0.075	0.087
Panel B: Medium banks (95∼99%)					*(90∼98%)*
CAP_{t-1}	0.015	0.064*	0.019	0.017	−0.035
	(0.042)	(0.035)	(0.039)	(0.045)	(0.024)
CAP_{t-1}*C	−0.024	−0.046	0.080	0.040	−0.022
	(0.062)	(0.070)	(0.053)	(0.083)	(0.044)
LIQ_{t-1}	0.059***	0.042***	0.021	0.026*	0.060***
	(0.013)	(0.011)	(0.013)	(0.014)	(0.010)
LIQ_{t-1}*C	−0.009	0.051*	0.018	0.061	0.055**
	(0.026)	(0.030)	(0.027)	(0.040)	(0.022)
CAP_{t-1}*LIQ_{t-1}	0.001	−0.000	0.002	0.002	0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
CAP_{t-1}*LIQ_{t-1}*C	0.002	−0.005	−0.002	−0.007	−0.006**
	(0.004)	(0.005)	(0.004)	(0.007)	(0.003)
Observations	18,632	17,323	18,632	16,775	40,175
Adjusted R^2	0.112	0.115	0.109	0.068	0.113
Panel C: Small banks (<95%)					*(<90%)*
CAP_{t-1}	0.110***	0.133***	0.104***	0.108***	0.111***
	(0.006)	(0.005)	(0.006)	(0.007)	(0.006)
CAP_{t-1}*C	0.049***	0.036***	0.054***	0.025**	0.056***
	(0.008)	(0.007)	(0.007)	(0.012)	(0.008)
LIQ_{t-1}	0.072***	0.054***	0.066***	0.070***	0.073***
	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)
LIQ_{t-1}*C	0.002	0.014***	0.009**	0.004	-0.002
	(0.004)	(0.004)	(0.004)	(0.005)	(0.005)
CAP_{t-1}*LIQ_{t-1}	−0.001***	−0.001***	−0.001***	−0.001***	−0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
CAP_{t-1}*LIQ_{t-1}*C	−0.001*	−0.000	−0.001***	−0.000	−0.001**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	498,895	461,751	498,895	447,957	473,150
Adjusted R^2	0.127	0.135	0.130	0.097	0.129

Notes: This table summarizes the coefficients related to the capital ratio (CAP_{t-1}) and liquidity ratio (LIQ_{t-1}) variables from the fixed effects regression results. All other bank-specific characteristic variables and macroeconomic control variables are included, but the coefficients are not reported because of space limitations. The dependent variables are quarterly real growth rates of net loans and unused commitments ($CREDIT_t$). Large banks are banks with total assets above the 99th percentile, medium banks are those with total assets from the 95th to 99th percentiles, and small banks include all other banks with total assets less than the 95th percentile in each period. Alternative measures for the liquidity ratio are used in Eqs. (1) and (2): LIQ1 = cash and balance due from depository institutions + US government securities + federal funds sold and reverse repurchases, and LIQ2 = cash and balance due from depository institutions + available-for-sale securities + federal funds sold and reverse repurchases. The crisis dummy assumes a value of 1 for the period from 2007 Q3 to 2009 Q2 except for Eq. (3); the crisis dummy in Eq. (3) equals 1 for the period from 2007 Q3 to 2010 Q4. The sample period extends from 1993 Q1 to 2010 Q4 except for Eq. (4), which spans from 1993 Q1 to 2008 Q3. In Eq. (5), alternative criteria for bank size category are used: large banks are banks with total assets above the 98th percentile, medium banks are banks from the 90th to 98th percentiles, and small banks are below the 90th percentile. Capital ratios (CAP_{t-1}) are normalized to minimum regulatory requirements, 8%. Liquidity ratios are normalized to mean values by each size category. All regressions include yearly dummies and quarterly dummies to capture business cycle conditions and control for seasonal influences. Constant terms are included, but not reported. Robust standard errors, clustered at the bank level, are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

is examined to validate the robustness of the main results. The results, reported in specification (4) in Table 5, show that the effect of an increase in capital ratio on credit growth is positively associated with the liquidity ratio, even when the period following the implementation of TARP capital injections is excluded.

Fourth, we conduct the same regressions using the expanded definition for bank size classification: the large banks are banks above the 98th percentile, the medium banks are banks from the 90th to 98th percentiles, and the small banks are those below the 90th percentile. Specification (5) in Table 5 shows that the results are generally comparable to those for the sample of banks above 99th percentile, although the magnitude of the coefficient for the variable of interest is lower. These results seem plausible because a higher number of small banks are included in the sample of large banks.

Finally, two other regulatory capital ratios—the tier 1 risk-based capital ratio (*TIER*) and the leverage ratio (*LEV*)—are examined instead of the total risk-based capital ratio (CAP). Table 6 reports regression results for two capital ratios. Regressions include not only main regression but also all of the regressions previously per-

Table 6
Robustness checks for large banks—regressions using two alternative capital ratios.

$L = CREDIT$	Main regressions	Alternative measures for liquidity		CRISIS (07q3∼10q4)	Pre-TARP cPeriod	Alternative criteria for bank size
		LIQ1	LIQ2			
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Tier 1 risk-based ratio ($TIER_{t-1}$)						
$TIER_{t-1}$	−-0.097	−0.037	−0.061	−0.146	−0.109	0.078
	(0.107)	(0.125)	(0.119)	(0.118)	(0.128)	(0.059)
$TIER_{t-1}$*C	−0.417*	−0.611**	−0.585**	0.014	−0.337	−0.278**
	(0.222)	(0.272)	(0.250)	(0.120)	(0.295)	(0.122)
LIQ_{t-1}	0.060*	0.046	0.034	0.060*	0.056	0.032
	(0.034)	(0.037)	(0.039)	(0.035)	(0.036)	(0.027)
LIQ_{t-1}*C	−0.172***	−0.180***	−0.172***	−0.150***	−0.174**	−0.096**
	(0.057)	(0.063)	(0.065)	(0.051)	(0.068)	(0.038)
$TIER_{t-1}$*LIQ_{t-1}	0.010***	0.008*	0.009*	0.011***	0.012***	0.002
	(0.003)	(0.004)	(0.004)	(0.003)	(0.003)	(0.003)
$TIER_{t-1}$*LIQ_{t-1}*C	0.021**	0.036***	0.031**	0.006	0.021**	0.012***
	(0.008)	(0.014)	(0.013)	(0.004)	(0.011)	(0.004)
Observations	3,849	3,849	3,590	3,849	3,505	8,051
Adjusted R^2	0.098	0.092	0.095	0.098	0.076	0.088
Panel B: Leverage ratio (LEV_{t-1})						
LEV_{t-1}	0.141	0.108	0.138	0.116	0.125	0.167*
	(0.140)	(0.148)	(0.167)	(0.149)	(0.155)	(0.089)
LEV_{t-1}*C	−0.815***	−0.764***	−0.835***	−0.310*	−0.713**	−0.417***
	(0.278)	(0.279)	(0.301)	(0.177)	(0.326)	(0.154)
LIQ_{t-1}	0.140***	0.094**	0.125**	0.134***	0.141***	0.094***
	(0.046)	(0.042)	(0.056)	(0.042)	(0.047)	(0.034)
LIQ_{t-1}*C	−0.198***	−0.162***	−0.167***	−0.188***	−0.195***	−0.105***
	(0.060)	(0.060)	(0.064)	(0.055)	(0.073)	(0.035)
LEV_{t-1}*LIQ_{t-1}	−0.005	0.000	−0.012	−0.002	−0.004	−0.011
	(0.012)	(0.011)	(0.015)	(0.011)	(0.012)	(0.009)
LEV_{t-1}*LIQ_{t-1}*C	0.031***	0.039***	0.034**	0.021***	0.031**	0.016***
	(0.011)	(0.015)	(0.015)	(0.007)	(0.013)	(0.006)
Observations	3,849	3,849	3,590	3,849	3,505	8,051
Adjusted R^2	0.096	0.089	0.093	0.095	0.072	0.088

Notes: This table summarizes the coefficients related to two alternative capital ratios ($TIER_{t-1}$ and LEV_{t-1}) and the liquidity ratio (LIQ_{t-1}) variables from fixed effect regressions results for large banks. Tier-1 risk-based ratio ($TIER_{t-1}$) and leverage ratio (LEV_{t-1}) are used for panels A and B, respectively. All other bank-specific characteristic variables and macroeconomic control variables are included, but the coefficients are not reported. Large banks are banks with total assets above the 99th percentile. Eq. (1) replicates results from Eq. (2) in Table 4. Alternative measures for the liquidity ratio are used in Eqs. (2) and (3): LIQ1 = cash and balance due from depository institutions + US government securities + federal funds sold and reverse repurchases, and LIQ2 = cash and balance due from depository institutions + available-for-sale securities + federal funds sold and reverse repurchases. The crisis dummy assumes a value of 1 for the period from 2007 Q3 to 2009 Q2 except for Eq. (4); the crisis dummy in Eq. (4) equals 1 for the period from 2007 Q3 to 2010 Q4. The sample period extends from 1993 Q1 to 2010 Q4 except for Eq. (5), which spans from 1993 Q1 to 2008 Q3. In Eq. (6), an alternative criterion for large banks is used; large banks are banks with total assets above the 98th percentile. Capital ratios are normalized to minimum regulatory requirements, 4%. Liquidity ratios are normalized to mean values by each size category. All regressions include yearly dummies and quarterly dummies to capture business cycle conditions and control for seasonal influences. Constant terms are included but not reported. Robust standard errors, clustered at the bank level, are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

formed for the robustness checks. The results generally remain unchanged.[20]

7. Conclusions and policy implications

Using the 1993 Q1–2010 Q4 unbalanced quarterly observations of insured US commercial banks, this study examines whether the effect of bank capital on lending differs depending upon the liquidity level. First, we show that the results differ by bank size. Only for large banks, we find that the effect of an increase in bank capital on credit growth is positively associated with the liquidity level. This finding suggests that the effect of an increase in bank capital on credit growth is significantly negative at low liquidity ratios, becoming significantly positive only after large banks retain sufficient liquid assets. This interaction effect is found to be nonsignificant or negligibly negative for medium and small banks. Notably, this interaction effect is more substantial for large banks during the recent financial crisis, but the results remain steady only when unused commitments are included in the definition of lending.

This study contributes to the literature in two ways. First, it shows that the interaction effect of bank capital and liquidity on credit growth is significant, implying that bank capital and lending exhibit a complicated relationship rather than a linear relationship. Second, this study demonstrates that unused commitments should be considered when examining the effect of bank capital on lending. Because the amount of loans can be increased from the conversion of unused commitments regardless of banks' willingness to do so, the results can be misleading when the role of unused commitments is not considered.

Our results also suggest several important policy implications. First, policy actions intended to sustain bank lending (e.g., capital injections and liquidity support) are complementary and should be congruously implemented to be effective,[21] particularly for large banks.

Second, recent international regulatory reform efforts that underscore the importance of both sufficient capital and liquidity management are supported for mitigating the effects of external negative economic shocks on banks' intermediation capacity. The results particularly support the effectiveness of countercyclical cap-

[20] Regression results for medium and small banks are not reported, but they rarely change. The results are available upon request.

[21] Although our results support overall direction of policies sustaining capital and liquidity, the effectiveness of such programs implemented during the financial crisis is arguable. While Berger et al. (2015) find that such programs increased aggregate lending, Wu (2015) finds only marginal effects in increasing bank syndicated lending. Wu (2015), however, do not rule out the possibility of increasing other types of bank lending.

ital buffer, LCR, and NSFR,[22] all of which possess a countercyclical feature. More specifically, these newly introduced rules require banks to accumulate more capital and liquid assets than in normal times, but the requirements are designed to be relaxed following external economic shocks, as judged by national authorities. If these requirements relax when banks suffer from a lack of capital and liquid assets, we speculate that similar effects to capital injection and liquidity support might arise; however, newly imposed liquidity regulations can alter bank behavior in unexpected ways.[23]

Third, large banks behave differently from medium and small banks, particularly during crisis periods. This difference in behavior can support implementing policy actions and regulations based on bank size.

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[22] The Liquidity Coverage Ratio (NCR) and the Net Stable Funding Ratio (NSFR) are developed to ensure that banks have sufficient high quality liquid assets and a sustainable maturity structure of assets and liabilities to survive a severe stress scenario lasting for one month and for one year, respectively (see BCBS, 2011).

[23] Cetina and Gleason (2015) express concerns regarding the effects of LCR. For instance, LCR can be manipulated with repos and reverse repos, and pressures caused by concerns about potential negative signaling effects can induce banks to maintain LCRs above 100 percent, even during times of stress. Furthermore, Calomiris, Heider, and Hoerova (2015) and Acharya, Mehran, and Thakor (2016) discuss the unexpected negative effects of the recent regulatory reforms or demonstrate fundamental shortcomings, thus suggesting adjustments to capital and liquidity requirements.