Bank Countercyclical Capital Buffer (CCyB) under the Liquidity Coverage Ratio (LCR) Regulation

Helyoth Hessou[a,b], Van Son Lai [b,c]

We acknowledge the financial support from the Autorité des Marchés Financiers (AMF), the AMF Integrated Risk Management of Financial Institutions Research Fund, the Conrad Leblanc Fund, and the Social Sciences and Humanities Research Council of Canada. We appreciate the insights from Michael Kiley from the Federal Reserve Bank and Maarten R.C. van Oordt from the Bank of Canada. We thank Georges Dionne, participants at the 52nd Canadian Economic Association conference at McGill University, Michael Bourdeau-Brien, Jean-Marie Gagnon, Alain Bélanger, Claudia Champagne, Franck Coggins, Éric Epkinda, Ali Ghali, and Charli Tandja for their valuable comments on previous versions of this manuscript.

[a] Department of Finance, Business School, Université de Sherbrooke, Quebec, Canada; helyoth.hessou@usherbrooke.ca
[b] Department of Finance, Insurance and Real Estate, Faculty of Business Administration, Laval University, Quebec, Canada; vanson.lai@fsa.ulaval.ca
[c] IPAG Business School, Paris

Bank Countercyclical Capital Buffer (CCyB) under the Liquidity Coverage Ratio (LCR) Regulation

Abstract

We study the interrelationship between the Basel III macroprudential countercyclical capital buffer (CCyB) and the liquidity coverage ratio (LCR) requirements. We show that LCR comes with a risk-liquidity trade-off nonexistent in Basel II. Banks trade-off the advantage of a safe asset in terms of its weight contribution to LCR with its opportunity cost of a lower return or a lower weight contribution to future capital positions. We derive a partial equilibrium model to show that LCR affects the CCyB required level to dampen the cyclicality in bank actual capital ratios. We find that an add-on of 4.6% of 'output gap variation' is sufficient to mitigate cyclical changes in US bank capital ratios during 1996-2011. Given an output gap drop of 6% during the 2007 Global Financial Crisis (GFC), when there was no bank liquidity regulation, our finding suggests that lowering 1% the minimum Basel capital ratio requirement (from 8% to 7%), would have been sufficiently accommodative during this crisis. Following the COVID-19 outbreak in 2020, thanks to Basel III reforms, banks hold higher levels of common equity capital post-GFC than pre-GFC. This enables the USA, Canada and many countries around the world to cut their CCyB requirements, providing banks with the capital to support lending and the banking industry to preserve and boost capital to weather robustly the current pandemic crisis.

JEL classification: E32; E44; G21; G28

Keywords: Basel III, Capital ratios, Liquidity rules, LCR, NSFR, Cyclical behavior

1. Introduction

Ravages from the 2007 Global Financial Crisis (GFC) have prompted regulators and policy makers worldwide to address pending issues on the Basel II framework. To address the cyclical variation in banks' capital and its negative impact on lending, a countercyclical minimum capital buffer (CCyB), a prominent feature in Basel III, was introduced in 2010.[1] A capital buffer is an amount of additional capital held by banks on top of the minimum requirement. Behn et al. (2016a) echo this issue by showing how German banks reduced their lending activities by 2.1 to 3.9 percentage points during the GFC following a 0.5 percentage points increase in capital charge (i.e., capital requirement). The Basel III macroprudential CCyB aims to smooth banks minimum capital charge through the cycle, by increasing the minimum capital ratio (8% under Basel II) by an additional up to 2.5% when credit expansion in the economy is deemed excessive. The 2020 COVID pandemic is bringing to the fore the role of CCyB. As a matter of fact, the US, Canada and numerous countries worldwide have cut their CCyB requirements to provide banks with the capital to support vital lending (Arbatli-Saxegaard and Muneer, 2020; Drehmann et al., 2020; Lewrick et al., 2020).[2]

While there is evidence that CCyB helps to smooth the minimum capital charge throughout the cycle, there is no evidence that banks' actual capital ratios remain less cyclical (e.g., Rogers (2018)). In this paper, given that banks use their own internal models to guide their adjustments of target capital levels, we study the cyclicality issues in bank reported and observed capital. To this end, we develop a partial equilibrium model to endogenize the bank capital adjustment behavior and quantify the required CCyB level in order to reduce or to nullify bank equity-to-loan ratios cyclical variations.

The mechanism that drives bank capital cyclical variations goes as follows. Let us subject banks to a minimum capital ratio of 8% of their risk-weighted assets. Since asset risk charges depend on the borrower probability of default, they vary with the business cycle.

[1] In fact, CCyB is an old idea, see Koch et al. (2020) for an interesting comparison of the behavior of large and highly-connected commercial banks during booms before the Great Depression (1921-1929) and Great Recession, i.e., GFC (2002-2007).
[2] At the end of 2020, the Federal Reserve Board has voted to affirm the CCYB at the current level of 0 percent, see https://www.federalreserve.gov/newsevents/pressreleases/bcreg20201218c.htm.

Banks find much more demanding in meeting capital charges in recessions than in expansions.[3] When the economy expands, being less constrained by the regulatory limit of 8%, the bank level of capital increases from both higher retained profits and lower asset risks. When a recession hits the economy, most banks are unprepared and with lower profits and increased bank asset risk, their accumulated capital buffers deplete quickly. Banks are left with the only option of raising fresh external capital or/and reducing their risk exposure. Since raising capital is costly in gloomy times, banks are more likely to reduce their new lending or cut in existing loans. Since it reduces banks' ability to lend in bad times, the minimum capital requirements sensitivity to the business cycle and the consequent bank adjustments are considered as the major bank capital regulation drawbacks.

Reforms to address the cyclical variation in banks' capital ratios were initiated at the 2008 Sao Paulo G20 meeting.[4] To address the issue of the cyclical variation of banks' capital ratios, the Basel Committee on Bank Supervision (BCBS) released a document providing guidelines for designing the countercyclical capital buffer (CCyB) measures (BCBS, 2011). Some countries with large banking systems have already activated the Basel III CCyB. The US has implemented the CCyB on October 14, 2016.[5] Following concerns about excessive credit growth, several countries in Europe have released a nonzero countercyclical buffer (CCyB), for instance, England (1% of risk-weighted assets (RWA) since November 2017) and France (0.5% of RWA since June 2018).[6] Activating capital buffers in periods of excessive credit growth reduces banks' excessive asset expansion at the costs of forgone output growth. Effectively, Auerand and Ongena (2016) find that the CCyB implemented in 2012 to curb mortgage lending in Switzerland has pushed banks to

[3] Jokivuolle et al. (2014) show that the bank optimal (or target) capital is likely to increase during a downturn due to the decline in the borrowers projects' success probabilities. Based on Spanish firms loan portfolios, by means of through-the-cycle assets' default probabilities, Repullo et al. (2010) find that the required level of capital requirement varies between 7.6 % and 11.9 % of the bank's portfolio exposure. Likewise, for firms with S&P ratings, Kashyap and Stein (2004) document an average change in capital charges between 35% and 40%.

[4] See Repullo and Saurina (2011) for an early discussion.

[5] The policy was announced on September 8, 2016 (see Brave and Lopez (2019)), for a full description of the policy, see Title 12 of the Code of Federal Regulations, Part 217, Appendix A.

[6] For a complete list of BIS (Bank of International Settlements) members that have activated a non-zero CCyB, see https://www.bis.org/bcbs/ccyb/. For European countries, see https://www.esrb.europa.eu/national_policy/ccb/all_rates/html/index.en.html.

shift their mortgages into small firms loans which were unconstrained by the regulation in question.

To undertake this research, we borrow from the large literature on bank optimal capital and procyclical behavior, not only *theoretical* (e.g., Blum and Hellwig, 1995; Estrella, 2004) but also *empirical* (e.g., Ayuso et al., 2004; Kashyap and Stein, 2004; Jokipii and Milne, 2008; Guidara et al., 2013 and Behn et al., 2016a).

With objectives clearly different from ours, to study the impact of the joint regulation of capital and liquidity, authors such as De Nicolò et al. (2014) and Hugonnier and Morellec (2017) among others, employ dynamic banking models. For instance, Hugonnier and Morellec (2017) focus their attention on the impact of the joint regulation of both of these ratios on bank solvency. Other researchers use dynamic stochastic general equilibrium models (DSGE) to study potential ramifications of CCyB on some macroeconomic variables and CCyB welfare effects. These studies recognize the usefulness of the Basel III CCyB as a tool to reduce volatility in aggregate macroeconomic variables and to improve the overall economic welfare. Karmakar (2016) develops a DSGE model with financial intermediation activities and shows that CCyB are useful in reducing volatility (macro variables and shocks) and raising economic welfare. Benes and Kumhof (2015) show that CCyB not only increases welfare but also reduces the need of implementing other countercyclical policy rates. Bekiros et al. (2018) study banks' reaction to different countercyclical buffers (CCyB) after shocks to banks' capital. They find that the countercyclical rule that reacts to deviations of credit to its steady state proves to be the most powerful tool in enhancing the banking stability with banks building up more capital.[7]

Heid (2007), among others, shows that capital buffers can mitigate the cyclical behavior of banks' capital ratios. Francis and Osborne (2012) show that while bank overall capital

[7] Another strand of literature focuses on alternatives to CCyB. Using a large sample of more than 4,000 banks scattered through 46 countries, Morgan et al. (2019) show that measures such as loan-to-value (LTV) ratio are powerful compared to others macroprudential rules in curbing excessive development in the housing market. However, their analysis recognizes the complementary role of other prudential rules in strengthening the effectiveness of the LTV ratio. Based on a natural experiment on Spanish banks, Jiménez et al. (2017) suggest that countercyclical provisioning is more effective in addressing cyclical variations in bank capital ratios. They show that the countercyclical provisioning requirement introduced in the Spanish banking system in 2000 has contributed to the stabilization of bank credit during the GFC.

requirements affect bank desired capital ratios, the resulting capital and lending adjustments propel the gap between actual and target ratios. Since banks retain most of their earnings to meet capital requirements, cyclical variations in their earnings are also likely to affect the cyclical variations of their capital ratios.

To the best of our knowledge, our paper is the first to provide a partial equilibrium model to quantify both the cyclical variation in banks' actual capital ratios and the countercyclical capital buffer that is necessary to mitigate cyclicality of bank capital ratios.

First, extending the analysis by Heid (2007), we account for the following stylized facts on banks' capital adjustment behavior, 1-the presence of capital buffers that banks hold on top of the minimum capital requirements, 2-the existence of banks internal capital targets that are different from the regulatory minimum requirements, and 3-the explicit analysis of cyclical variations in bank assets and profitability.[8]

Second, in a novel fashion, we account for the effects of the new Basel III liquidity rules on the required CCyB. We rely on the Basel III framework and definitions to identify the channels through which the liquidity rules, namely the bank liquidity coverage ratio (LCR), defined as the weighted sum of high quality liquid assets (HQLA) over the short term net outflows, can affect bank capital requirements and, as a result, the CCyB level. We expect LCR to affect the countercyclical measure effectiveness in various ways. HQLA, the numerator of LCR is obtained as weighted sum of banks assets, with the liquidity weights inversely related to credit risk. This introduces a new trade-off between asset risk and liquidity since the higher an asset risk, the lower its liquidity weight and its contribution to LCR. To meet the liquidity requirement, banks arbitrage between profitable risky securities and less risky securities. Like asset-risk weights used to compute capital ratios, liquidity weights are also cyclical and they drive bank portfolio adjustments through the cycle. Furthermore, we expect the LCR cyclicality effects to be reinforced by runs on wholesale funds in recessions causing the denominator of LCR to become bigger. Therefore, banks

[8] For the literature on the relation between bank profitability and business cycle fluctuations, see Albertazzi and Gambacorta (2009) and Bolt et al. (2012) among numerous others.

hoard liquid assets (the numerator of LCR) as experienced during the GFC (see e.g., Berrospide, 2013) or reduce their deposit outflows by investing in stable funding. When it is binding, the liquidity requirement hurts banks' future profits. As banks rely on profits to meet minimum capital requirements, changes in the composition of HQLA affect bank future profitability, and consequently their ability to adjust capital ratios and to make lending decisions properly (see Bonner and Eijffinger, 2016).

In sum, the contribution of our paper is twofold: 1- by means of a simple banking partial equilibrium model, we derive the required optimal CCyB to offset cyclicality in the bank capital ratio, and 2- by studying how the Basel III liquidity rule procyclicality drives the effectiveness of the countercyclical measures, we contribute to the debate surrounding the interrelationship between the different Basel III regulations.

Towards this end, after deriving a bank optimal countercyclical capital buffer (CCyB) model, we calibrate it using an extensive database on 3,725 American (US) banks spanning the period 1996-2011 totalizing 59,600 bank year observations.[9] Since bank size affects risk-taking behavior, we divide our sample in three subsamples equally represented (small, medium and large banks), using the distribution of banks' asset in year 2011. Our calibration exercise suggests that an add-on of 4.6% of "output gap variation" above the minimum capital ratio of 8% is sufficient to alleviate the cyclical changes in banks' actual capital ratio. Since we experience an output gap drop of 6% during the GFC (where no liquidity rule was in effect), our finding suggests that one percent drop (from 8% to 7%) in the minimum Basel capital ratio requirement would have been sufficiently accommodative for banks throughout GFC. A study by Occhino (2018) also advocates a 1% reduction in the Tier 1 capital ratio for US banks during the GFC.

Following the COVID-19 outbreak, Basel III capital and liquidity buffers are being relaxed. Key findings from this paper which have materially manifested in the aftermath of the current COVID-19 pandemic are the following: 1- policymakers need to account for

[9] With the new Basel III capital guidelines released in 2011, banks have been adjusting their portfolios of activities in preparation for these forthcoming regulations. To avoid confounding results, we limit our data to the period before 2011.

the potential effects of LCR when designing CCyB, 2- relaxing the LCR requirement during downturns or setting the countercyclical LCR requirement might be desirable to contain LCR cyclicality and its potential effects on the cyclical variations of bank capital ratios, and 3- the LCR impact on the CCyB required level is attributable to the risk-liquidity trade-off that comes with the LCR requirement.

Our study is also close to the literature on the quantification of the countercyclical capital buffer calibration. Repullo et al. (2010) suggest anchoring the countercyclical measure to the gross domestic product growth. They find that applying a multiplier of 6.5% to the GDP growth standard deviation to the minimum requirement ratio (on average) is sufficient to smooth the variation in bank capital minimum requirements. In the same vein, van Oordt (2018) calibrates the required level of CCyB to prevent bank serious breach of capital through the cycle. Based on market stress scenarios, to allow regulators to anticipate periods of excessive credit growth, van Oordt (2018) finds a CCyB ranging from 1.4 to 1.7 per cent of bank total assets necessary. We share with van Oordt (2018) the same approach of working directly with bank actual capital. However, we differ from him because we not only explicitly models the sources of cyclical variations in bank capital ratios but also derive the endogenous optimal buffer using the average banks' characteristics. Furthermore, by mimicking the current Basel III CCyB framework, our approach can be straightforwardly implemented. We also do not rely on stock market data (unavailable for a large number of unlisted banks) but rather employ book data used by regulators to set minimum capital requirements. To guide CCyB activation decisions, Brave and Lopez (2019) forecast the transition probabilities between the states of high and low financial stability. Their approach provides an alternative to the debate on the best anchor to use for activating CCyB. Their analysis reveals that the CCyB activation by US policymakers at the end of 2016 was inappropriate.[10]

The rest of the paper is structured as follows. We describe the baseline model in Section 2 and derive the cyclical behavior of capital ratio in Section 3. We estimate the optimal

[10] There are studies on the real effects of the CCyB activation on bank actual capital ratios, however, this topic brings us too far and is beyond the scope of this paper.

equity-to-loan ratio under CCyB in Section 4 and extend it to account for the new Basel III LCR regulation in Section 5. To estimate the required CCyB size, we provide a calibration exercise in Section 6. In Section 7 we analyze LCR effects on CCyB and we conclude and offer policy implications in Section 8.

2. The model setup

We employ a simple partial equilibrium banking model built on Heid (2007) framework. There are three agents in the model, a representative risk-neutral bank, a depositor with deep pocket and a regulator. This type of model enables us to derive endogenously, explicit expressions for bank capital buffers consistent with the capital buffer levels documented in the empirical literature.[11]

2.1 The representative bank

The representative bank follows a repeated one-period decision rule with decisions taken at date 0 and outcomes observed at date 1.[12]

Table 1: The bank balance sheet at date 0

Assets	Liabilities and Equity
Bonds: B	Deposits: D
Loans: L	Equity/Capital: E

The risk-neutral banker starts with the balance sheet depicted in Table 1. He owns initial equity E and collects deposits D. Deposits (D) are insured by the regulator and assumed to earn zero (0) return. Collected funds ($E + D$) are invested in two classes of risky assets: Loans (L) and bonds (B). We assume that loans are more attractive than risky bonds in risk-adjusted terms.[13] The bank decision at date 0 is to choose an optimal loan level under constraints fixed by the regulator.

[11] Most of the theoretical literature on bank capital assumes that banks hold no capital buffer since capital is costly.
[12] Using one-period model can be justified by Estrella et al. (2004) finding. They suggest that under a dynamic framework, a typical bank capital constraint is tantamount to a period-by-period value at risk (VaR) with an endogenous probability of default, as it is the case in our framework. Jarrow (2013) shows that the VaR and leverage ratio rules for capital adequacy are equivalent.
[13] Relaxing this assumption does not change our model main findings. In a one-period model, since the bank faces no liquidity demand before its assets mature at date 1, there is no room for holding liquid assets. Hence, the choice of the loan level that maximizes the probability of meeting both the capital and liquidity minimum requirements drives the bank decision. After supplying an optimal loan volume, the bank invests the excess funds in risky bonds.

2.2 The regulator

The regulator aims to reduce the deposit insurance moral hazard incentive of excessive risk-taking. To facilitate depositors' repayment and limit the bank's probability of default at date 1, the regulator imposes at date 0 a minimum capital limit the bank has to comply at date 1. The minimum capital ratio in form of equity-to-asset risk ratio is as follows:

$$\frac{E+\pi}{w_L L + w_B B} \geq a \qquad (1)$$

where w_L and w_B are the risk-weights for banks loans (L) and risky bonds (B) respectively. $w_L L + w_B B$ is the total asset risk in terms of risk-weighted assets, a bank metric for equity-capital cushioning. Therefore, the regulator expects the bank to maintain at date 1, a minimum ratio of capital (consisting of initial equity E and bank total profit at date 1, π) to risk-weighted assets of *a*.

2.3 The bank objective function

Our bank maximizes its expected date 1 profit (π_1) under the regulatory constraints at date 0. To distinguish the contribution of equity-capital from the liquidity constraint, we first model the bank decision under the capital constraint and then introduce the liquidity constraint. We formulate the bank maximisation problem as follows:

$$\begin{gathered} Max_{L,B}\, \pi = (\rho - s)L + \gamma B \qquad (2) \\ s.t \\ prob(E + \pi \leq\ a(w_L L + w_B B)) \leq p, \\ B + L = D + E\,. \end{gathered}$$

The bank total profit at date 1, (π), is generated from loans with net return of $(\rho - s)$ and bonds with return γ.[14] ρ is the gross return on loans (known with certainty at date 0) and s is the random loan charge-off rate materialized at date 1. The uncertainty in the model is driven by s, which is assumed to follow a probability distribution with a cumulative function F, an expected value $\bar{s}$ and a volatility σ. s is the only source of uncertainty.

[14] We assume that there is no funding costs since deposits are fully insured and the shareholders extract entirely the earnings made at date 1.

Under a value at risk (VaR) framework, the capital constraint means that to adhere to the minimum capital requirement at date 1 with probability p, the bank chooses its ex-ante portfolio total assets ($A = L + B$). The ex-ante choice of the probability p, assumed exogenous, depends on the bank's perceived regulatory and compliance costs from falling below the minimum capital requirement at date 1. The capital constraint is similar to the one used in Estrella (2004) and Heid (2007. These authors find that under a dynamic framework, a typical bank capital constraint is tantamount to a period-by-period VaR with endogenous probability of default.

The last constraint is the balance sheet identity formula. It guarantees that the sources ($D + E$) and uses ($B + L$) of funds are equal.

Since the bank faces a linear profit function in L and B (and loans are assumed to be preferred more than bonds in risk-adjusted terms, i.e., $(\rho - \bar{s}) > \gamma$), maximizing π leads to investing the whole portfolio in loans. However, because of the higher capital requirement for risky loans, the banks will invest at date 1, equity E in loans. The remaining fund is invested in bonds. Therefore, the capital requirement and the balance sheet constraints are the bank equilibrium loan level main determinants.

3. The equilibrium equity-to-loan ratio

3.1 Solution to the banker problem

Solving the capital and the balance sheet constraints gives us the bank equilibrium equity-to-loan ratio (e^L) choice at date 0.

<u>Result 1:</u> Under the capital and balance sheet constraints, the bank's equilibrium loan-to-equity ratio at date 0 depends on the bank asset characteristics (risk, profitability and leverage) and the regulatory constraints as follows:

$$e^L = \lambda\big(\alpha + aw_L + (\gamma - aw_B) - (\rho - \bar{s})\big), \qquad (3)$$

with $\lambda = \frac{1}{1-\frac{A}{E}(aw_B-\gamma)}$, $\alpha = \sigma F_S^{-1}(1-p)$.

Proof: Insert Proof 1 here.

The following condition gives rise to a positive value of the equity-to-loan ratio: $(aw_B - \gamma) \leq \frac{E}{A}$, which is most likely the case.

The equity-to-loan ratio obtained from Result 1 exhibits interesting features. Consistent with intuition, it increases with higher volatility (σ) in the charge-off rate or credit risk s, via the term α in the equilibrium equation. It is also a positive function of the bank leverage ($\frac{A}{E}$) and the regulatory violation costs manifested in the compliance probability at date 1 (p, through α). Conversely, the optimal equity-to-loan ratio decreases with the level of expected profit at date 1, $(\rho - \bar{s})$, since with a higher profitability at date 1 the bank will meet the capital requirement at date 1 easily. λ measures the sensibility of most parameters featured in our model to the equity-to-loan ratio. Therefore, λ should be positive, if $(aw_B B - \gamma) \leq \frac{E}{A}$, we obtain this.

3.2 The cyclical behavior of the equilibrium equity-to-loan ratio

Recall our main objective is to estimate the required CCyB level to cope with cyclicality in the bank equity-to-loan ratio. To quantify the cyclical variations in the bank equity-to-loan ratio depicted by Equation 3, we take the derivative of e^L with respect to the business cycle. Since our model is static, we inject dynamics flavors by postulating that some of the modelled parameters and variables, such as the risk-weighted (w), the expected charge-off rate ($\bar{s}$), the deposit stock (D) and the leverage ($\frac{A}{E}$) are subjected to cyclical variations.

Since cyclical variations in the bonds (B) and loans (L) risk weights (w_B or w_L) are functions of the borrower probability of default, we assume these to co-move negatively with the business cycle.[15] We model this cyclical pattern in the following fashion:

[15] We assume that risk weights w are sensitive to economic cycles as large banks use the internal ratings-based (IRB) approach to calculate risk weights. By way of the standardised approach (see BCBS 2021a), small banks assigns standardised risk weights to exposures. In many jurisdictions, banks adjust their standardised risk weights to reflect credit ratings. Therefore, we assume that credit risk weights obtained from rating adjustments capture the impact of macroeconomic conditions. Furthermore, Cornett et al. (2020) among others find that stress test banks increase capital ratios and Schneider et al. (2020) document that responding to stress tests, the large trading banks make more conservative capital plans. Behn et al. (2016b) find that banks use internal model-based risk estimates to systematically underestimate their loan portfolios credit risk to save on capital and Plosser and Santos (2018) suggest banks by means of strategic use of internal models underreport risk to overcome capital constraints. Since stress tests increase bank capital and the use of internal risk model reduces capital, ignoring the impact of large banks regulatory capital stress tests and the use of internal risk models on CCyB would not distort unduly our results.

$$w_X(y) = w_0 - \frac{m_w^X}{a}(y - \bar{y}), \qquad (4)$$

where $X \in \{B, L\}$, w_0 is considered as the unconditional risk-weight and can be viewed as the risk charge in normal times. $\frac{m_w^X}{a}$ is the risk-weight sensitivity to the business cycle variable $(y - \bar{y})$.[16] We proxy for the cycle by the output gap, which is the difference between the gross domestic product (GDP) growth (y) and the potential GDP growth ($\bar{y}$), i.e., the attained GDP should the production factors have been used to their full potential.

By using the GDP gap (output gap) as a proxy for the cycle, we follow an approach akin to Kashyap and Stein (2004) analysis.[17] Note that the literature on the bank capital cyclical behavior largely employs the output gap or the GDP as proxies for the business cycle, (see Ayuso et al. 2004; Repullo et al., 2010, among others).

Regarding other drivers of bank capital cyclicality, we assume that the expected value of the default rate is negatively related to the cycle ($\bar{s}_y < 0$), while the bank deposits and leverage are positively related to the cycle $\left(D_y > 0; \left(\frac{A}{E}\right)_y > 0\right)$, which are sensible assumptions. Based on these sources of cyclical variations, we obtain the cyclical variations in the equity-to-loan ratio as follows.

Result 2: The sensitivity of the equilibrium equity-to-loan ratio e^L the business cycle is:

$$e_y^L = \lambda_y \frac{e^L}{\lambda} + \lambda\left(-m_w^L + m_w^B + \bar{s}_y\right), \qquad (5)$$

with, $\lambda_y = \frac{\frac{A}{E}_y(aw_B - \gamma) + \frac{A}{E}(-m_w^B)}{(1 - \frac{A}{E}(aw_B - \gamma))^2}$ and $\lambda = \frac{1}{1 - \frac{A}{E}(aw_B - \gamma)}$.

[16] $(y - \bar{y})$ is the business cycle variable where y is the economic cycle variable and $\bar{y}$ is its level when the economy is operating at its full potential (or the trend of y). Hence $(y - \bar{y}) > 0$ will be considered as an upturn (i.e., the economy is doing better than its potential level). Conversely, $(y - \bar{y}) < 0$ would signal a slow down of the economy.

[17] There is an ongoing debate regarding the choice of the best anchor to activate the countercyclical capital buffer. The choice of the credit-to-GDP gap by the Basel committee is consistent with Borio et al. (2010), Drehmann et al. (201) and Drehmann and Juselius (2013) studies. Drehmann and Juselius (2013) find that the debt service ratio (DSR) and the credit-to-GDP ratio are the best anchor respectively at long and short-term horizon. Against this view, Kashyap and Stein (2004) argue in favor of the GDP growth since there is evidence that the negatively correlated with the GDP growth credit-to-GDP gap potentially triggers the deployment of the capital buffer at the wrong time in the business cycle. Edge and Meisenzahl (2011) also criticize the reliability of the credit-to-GDP as an CCyB anchor, for an update see Drehmann and Yetman (2020) and Jokipii et al. (2020).

Proof: Insert Proof 2 here.

The first term ($\lambda_y e^L$) is proportional to the level of equity-to-loan ratio (e^L) and is either positive or negative depending on the sign of λ_y (which is negative if $aw_B - \gamma \leq 0$). The second term is likely negative ($m_w^L > m_w^B$). Overall, if the first term is negative, the equilibrium equity-to-loan ratio is likely to be a negative function of the business cycle, i.e., procyclical.

4. The banker problem under the CCyB requirement

4.1 An overview of the Basel III CCyB

In the previous section, we show that the equity-to-loan ratio can be negatively correlated with the business cycle. In this situation, banks are likely to shrink their assets or loans to adjust to an increasing equity-to-loan ratio during recessions (or periods in which the likelihood of a recession is high). The Basel III macroprudential CCyB requirement aims at increasing both the quantity and the quality of bank capital during periods of expansion by increasing the minimum capital ratio in increments up to 2.5% (BCBS, 2011).[18] Banks could then adjust to increases in the minimum ratio by raising their equities (E) in the starting period or by reducing their lending to the economy (the ratio denominator, see Equation 1). Since raising equity capital in recessions is prohibitive, banks are likely to curb credit by shrinking loans.

Once the CCyB requirement is activated, the CCyB framework stipulates that banks will be required to hold an additional common equity Tier 1 (CET1) capital that can increase to 2.5% of their risk-weighted assets (RWA). Studies conducted by the Bank for International Settlements (BIS) suggest that the CCyB should be activated when the credit-to-GDP ratio exceed 2%. In terms of implementation, the buffer is set to increase gradually to reach its

[18] Note that the capital buffers in Basel III are not limited only to CCyB. There is also the capital conservation buffer (CCB) and two other macroprudential elements for global systemically important banks (G-SIBs), such as the specific capital surcharge and the total loss-absorbing capacity (TLAC) requirement (see BIS-FSI Connect, 2019). Established above the regulatory minimum capital requirement, CCB set at 2.5% of total risk-weighted assets, can only be met with Common Equity Tier 1 (CET1) capital. Bank failure to maintain the required CCB triggers automatic constraints on capital distributions (for example, dividend payment, executive compensation, bonus) until they replenish CCB. Unlike CCyB, which is activated by regulators based on macroeconomics, CCB depends on bank internal capital management. We assume that our representative bank perception of the regulatory costs associated with the failure to meet the total capital minimum requirements including those imposed to large banks following stress tests subsumes into the CCB requirement.

maximum of 2.5% when the credit-to-GDP attain a value of 10%. To get the intuition behind CCyB, let us consider a bank with the following balance sheet:

Table 2: The bank balance sheet at date 0

Assets	Liabilities and Equity
Bonds: 20	Deposits: 95
Loans: 80	Equity/Capital: 5

Assume the risk weights associated to bonds and loans to be 0% and 50% respectively. A bank with the balance sheet described in Table 2 has a total risk-weighted asset (RWA) value of $40 (0%*$20+50%*$80). Since banks are required to hold in normal times at least 8% of their RWA as equity, the banks' minimum capital should be at least $3.2 (8%*$40). Suppose now that we are at the peak phase of credit expansion and that the regulator activates an additional 2.5% of risk-weighted assets. On top of the minimum $3.2 of equity, the bank will seek an additional capital of $1 (2.5%*$40) to increase its minimum requirement to $4.2 ($3.2+$1). Let a recession hits the economy and the overall borrowers' credit deteriorates. This causes an increase in the loan risk weights of 20% to 70%. Therefore, the bank's new minimum capital requirement should increase to $4.48 (8%*$56).[19] With CCyB in effect, the bank has maintained a minimum capital of $4.2. Therefore, it will seek an additional capital of $0.28. On the contrary, if CCyB were not activated, the banks would have been operating with a capital of $3.2 and they would have to increase it to $4.48. This would require an additional capital of $1.28 making it more demanding on the bank.

By requiring banks to hold an additional capital buffer during periods of excessive growth, policy makers aim to ease stress on bank capital when the economy enters a slowdown, as it is the ongoing case following the COVID-19 outbreak.

4.2 The equilibrium equity-to-loan ratio under the CCyB requirement

We assume that the regulator imposes a minimum capital ratio that varies with the business cycle as follows:

$$a(y) = a_0 + m_a(y - \bar{y}), \qquad (6)$$

[19] $56 is the RWA associated to the new risk-weight of 70% for loans.

where a_0 is the existing Basel II minimum limit of 8% and $m_a(y - \bar{y})$ the countercyclical capital adjustment component in the CCyB. By means of Result 1, which is a function of $a(y)$, we study the equity-to-loan cyclical behavior under the CCyB requirement and estimate the required CCyB level to offset cyclicality using Result 3 below.

<u>Result 3:</u> The equilibrium equity-to-loan ratio e^L obtained under the CCyB requirement which comoves positively with the cycle (and more so relative to the case with no CCyB requirement) is given by the following equation.

$$e_y^L = \lambda_y \frac{e^L}{\lambda} + \lambda\left(\boldsymbol{m_a}(\boldsymbol{w_L} - \boldsymbol{w_B}) - m_w^L + m_w^B + \bar{s}_y\right), \qquad (7)$$

with $\lambda_y = \frac{\frac{A}{E_y}(aw_B - \gamma) + \frac{A}{E}(\boldsymbol{m_a w_B} - m_w^B)}{(1 - \frac{A}{E}(aw_B - \gamma))^2}$ and $\lambda = \frac{1}{1 - \frac{A}{E}(aw_B - \gamma)}$.

Proof: Insert Proof 3 here.

The CCyB introduction reduces the likelihood of negative comovement of the equity-to-loan ratio over the business cycle. We highlight in bold the additional terms with positive sign in the CCyB equity-to-loan ratio expression. For example, the second term denoting the cyclical variation in the optimal equity-to-loan ratio $\lambda(\boldsymbol{m_a}(\boldsymbol{w_L} - \boldsymbol{w_B}) - m_w^L + m_w^B + \bar{s}_y)$ is no longer strictly negative due to the CCyB induced positive term $\boldsymbol{m_a}(\boldsymbol{w_L} - \boldsymbol{w_B})$. Furthermore, the new positive term $\boldsymbol{m_a w_B}$, is also likely to be positively related to the cycle. Therefore, by and large, the CCyB requirement makes the optimal equity-to-loan ratio to be less procyclical with the business cycle.

4.3 Adequate CCyB requirement (m_a)

As stated earlier, the CCyB requirement aims at absorbing (or reducing) any cyclicality in bank capital ratios and mitigating the impact of lending curb.[20] A rein on the equilibrium equity-to-loan ratio's cyclical component forces banks to maintain a stable equity-to-loan ratio through the cycle and to prevent banks cutting in new loans. For this purpose, we

[20] We refer to fact that the equity-to-loan ratio will vary with the cycle under the CCyB requirement through the term $m_a(y - \bar{y})$ in Equation 6.

determine the level of $\boldsymbol{m_a}$ or add-on capital required to offset the cyclical variation in the equilibrium equity-to-loan ratio.[21] Using Equation 7, we find m_a so that e_y^L= 0. In other words,

$$m_a^* = arg_{m_a} \left(\lambda_y \frac{e^L}{\lambda} + \lambda\big(m_a(w_L - w_B) - m_w^L + m_w^B + \bar{s}_y\big) = 0\right) \quad (9)$$

5. Potential impact of the LCR requirement on CCyB

In addition to the CCyB requirement, two new liquidity rules were introduced under Basel III (namely, the LCR (the Liquidity Coverage Ratio) and the NSFR (the Net Stable Funding Ratio)). LCR by changing bank liquid asset holdings affects the equilibrium equity-to-loan ratio (since the equilibrium equity-to-loan ratio depends on bank liquid asset holdings, such as the bond-to-loan ratio (b^L). More importantly, LCR by making banks' liquid asset holdings more sensitive to cycles, will affect the cyclical components of the optimal equity-to-loan ratio and consequently, the required CCyB.

Next, we investigate in details the potential effects of the Basel III LCR requirement on the CCyB levels we derive previously.

5.1 The liquidity coverage ratio (LCR) requirement

The liquidity crisis unfolded during the 2007 GFC has brought to the fore regulatory attention to the importance of monitoring banks liquidity. There is evidence that banks failed to adhere to sound liquidity management. Two main liquidity rules were introduced in the new Basel III framework, the liquidity coverage ratio (LCR) to improve banks' short-term resilience to liquidity shocks and the net stable funding ratio (NSFR) to reinforce banks' structural liquidity resilience. LCR, in particular, is designed to ensure that banks hold sufficient reserves of high-quality liquid asset (HQLA) to survive a period of significant liquidity stress lasting 30 days according to BIS (2018). We provide below a

[21] Since the implementation of CCyB during booms takes the form of higher capital requirements, capital-constrained banks could reduce credit supply to the economy. Since there are costs associated with CCyB implementation, an optimal CCyB should balance the costs and benefits in terms of the contribution to financial stability. We derive in this paper the level of CCyB that is needed to totally offset cyclicality in bank optimal equity-to-loan ratios. This level could be lower once the costs associated to CCyB are taken into account. We interpret the CCyB requirement in our study as a limiting case.

brief description of the LCR outlined by BIS (2018).[22] With loans not eligible for HQLA, the liquidity ratio (LCR) is computed as the ratio of High-Quality Liquid Assets (HQLA) to net outflows (30 days).

$$LCR = \frac{\text{High quality liquid assets}}{\text{Total net cash outflow over the next 30 calendar days}} \geq 100\% \,. \quad (10)$$

The stock of high-quality liquid assets (HQLA) is obtained as a weighted sum of assets eligible to meet the LCR requirement ($\sum_i a_i\, l_i$) where a_i are eligible asset categories (excluding loans) and l_i are the liquidity weights associated. The eligible assets are cash or assets that can be converted into cash quickly through sales (or by being pledged as collateral) with no significant loss of value. The contribution of the eligible assets depends on their liquidity weights or haircuts. Notably according to the BCBS guidelines, weights are inversely related to the eligible assets' credit risk.[23] The minimum requirement of 100% in the LCR was expected to be effective on January 1, 2019.[24]

5.2 The optimal equity-to-loan ratio under the LCR requirement

To analyze the implication of the LCR for the equilibrium equity-to-loan ratio, we add the LCR constraint into the bank optimization problem and estimate the bank equity-to-loan ratio. Our liquidity requirement mimics the Basel III short-term LCR liquidity rule and acts as an additional constraint for our representative bank's asset allocation. To keep the model simple, we ignore the other liquidity measure the net stable funding ratio (NSFR). To meet the liquidity demand in a thirty-day horizon, banks invest part of their funds in HQLA holdings. Since loans are not considered as HQLA, only bonds (risk-free or risky) matter for the LCR. Then, to indemnify insured depositors of closed banks, requiring banks to

[22] See the BIS (2018) document for a complete overview.

[23] For example, the liquidity weight of Level 1 assets as cash-like assets is 100% while their corresponding credit risk weight is 0%. The liquidity weight of Level 2 assets such as securities (with 20% of risk weight) is 85%. Other risky assets such as qualifying equity shares or RMBS (Residential Mortgage Back Securities) and securities with graded between A+ and BBB, register the lowest liquidity weight (58%). These numbers suggest that the liquidity weight applied to an asset is inversely proportional to its credit risk, the higher the asset risk (high RWA), the less it contributes to the HQLA. The denominator of the LCR ratio is computed as the minimum between 75% of outflows and the difference between expected 30 days inflows and outflows. The denominator of the ratio (the expected outflow) is defined according to BIS (2018) as the total expected cash outflows minus the total expected cash inflows found in the stress scenario. A total expected outflow is determined by multiplying the outstanding balances of various categories of liabilities and off-balance sheet commitments by the supervisory rates at which they are expected to run off or be drawn down. Total expected cash inflows are estimated by applying inflow rates to the outstanding balances of various contractual receivables. The difference between the stressed outflows and inflows is the minimum size of the stock of HQLA.

[24] Specific timing of the LCR implementation varies with the country objectives. Internationally, it was expected that LCR became effective on 1 January 1, 2015. To avoid disruption in the orderly strengthening of banking systems and the ongoing financing of economic activities, banks will be required to hold a minimum LCR, initially set at 60% and raised annually by 10 percentage points to reach 100% on January 1st 2019.

hold a minimum level of liquid assets which is proportionate to both bank deposits and expected profitability facilitates and bonifies regulatory asset liquidation at date 1 (see Calomiris et al., 2016).

Now, let us motivate the specification of our LCR constraint. Recall that under the LCR regulation, liquidity weights assigned to assets are negatively proportional to corresponding risk weights. Moreover, loans are not eligible as liquid assets under the LCR requirement. Without loss of generality, we set the bank's total HQLA (High Quality Liquid Asset) equal to $(1 - w_B)B$. For the denominator of the ratio, i.e., the net outflows, we consider as inflows the expected profit at date 1 and as outflows, the deposits' repayment at date 1. Then, the LCR constraint takes the following form :

$$LCR = \frac{(1 - w_B)B}{\delta D - (\rho - \bar{s})L - \gamma B} \geq 1$$

or, equivalently $(1 - w_B)B \geq \delta D - (\rho - \bar{s})L - \gamma B$.

Since loans offer higher expected returns than bonds, we assume that the constraint binds and banks will hold exactly the required minimum level of liquid assets. We obtain then the LCR constraint:

$$(1 - w_B)B = \delta D - (\rho - \bar{s})L - \gamma B. \qquad (11)$$

Below, by including the balance sheet constraints in the LCR constraint and dividing total bonds (B) by total loans (L), we get the bond-to-loan ratio b^L.

$$b^L = \xi(\varphi - \delta e^L),$$

with $\xi = \frac{1}{1 - w_B + \gamma - \delta}$ and $\varphi = \delta - (\rho - \bar{s})$.

We plug the bonds-to-loan ratio b^L value obtained from Equation 11 in the equity-to-loan ratio under the LCR requirement and we obtain the following Results 4 and 5.

<u>Result 4:</u> The equilibrium equity-to-loan ratio under the LCR requirement takes the following form:

$$e^L = \phi\big(\alpha + aw_L + \xi\varphi\,(aw_B - \gamma) - (\rho - \bar{s})\big), \qquad (12a)$$

where $\phi = \frac{1}{1 + \xi\delta(aw_B - \gamma)}$.

Proof: Insert *Proof 4* here.

As compared to the case without the liquidity requirement (Equation 3), the equilibrium equity-to-loan ratio e^L depends on the deposit haircut δ (a key parameter for the LCR constraint equation) fixed by the regulator. The haircut affects both the value of the equity-to-loan ratio and the equity-to-loan ratio sensitivity (through the multiplier ϕ) to other parameters such as credit risk, profitability and compliance costs. It is worth noting that the bank leverage, contrary to the No-LCR case, $(\frac{A}{E})$ no longer affects the optimal equity-to-loan ratio.

__Result 5__: The cyclical behavior of the capital ratio under the LCR requirement is driven by the same factors as in the non-LCR case, with the LCR parameter δ affecting the equity-to-loan ratio sensitivities to other decision parameters and the equity-to-loan ratio cyclical behavior.

$$e_y^L = \phi_y \frac{e^L}{\phi} + \phi\big(\boldsymbol{m_a w_L} - m_w^L + (aw_B - \gamma)(\xi_y \varphi + \xi \bar{s}_y) + (\boldsymbol{m_a w_B} - m_w^B)\xi\varphi + \bar{s}_y\big), (12b)$$

with $\phi_y = \frac{-\xi_y \delta(aw_B - \gamma) - (\boldsymbol{m_a w_B} - m_w^B)\xi\delta}{(1+\xi\delta(aw_B-\gamma))^2}$ and $\xi_y = \frac{-m_w}{a(1-w+\gamma-\delta)^2}$.

As in the Equation 9 case, we can compute the required CCyB level to offset the cyclical variation in capital ratio under the LCR requirement as follows.

$$m_a^* = arg_{m_a}\left(\phi_y \frac{e^L}{\phi} + \phi\big(\boldsymbol{m_a w_L} - m_w^L + (aw_B - \gamma)(\xi_y \varphi + \xi \bar{s}_y) + (\boldsymbol{m_a w_B} - m_w^B)\xi\varphi + \bar{s}_y\big) = 0\right) (12c)$$

6. Calibration and empirical evidence

In this section, to study the effects of LCR requirement, we perform an empirical calibration of our model. Recall that by focussing on the level of CCyB (m_a^*) that is necessary to contain the equity-to-loan ratio cyclical behavior, we have derived, in the above, several results. Now, using US bank data, we calibrate the parameters in the

CCyB expressions (see Equations 9 and 12c) and solve the nonlinear equations to obtain CCyB values.[25]

6.1 Calibration

We rely on a US commercial banks extensive database. We extract financial statement data from the Wharton Research Data Service (WRDS). The sample consists of 59,600 bank-year observations on 3,725 banks spanning the period 1996-2011. As Basel III capital guidelines were released in 2011, we limit our data to the period before 2011 to avoid confounding and contamination, as banks would then have prepared their regulatory compliance. Data on bank risk-based capital and leverage ratios are available only from 1996.[26] We download US macroeconomic data from the Federal Reserve Economic Data (FRED), a database maintained by the Research division of the Federal Reserve Bank of St. Louis. In fact, the Basel I international capital standards were not fully implemented in the US until 1992. Since bank size affects risk-taking behavior, using terciles of the banks' total assets distribution, in year 2011, based on the first, second and third terciles, we divide our sample in three subsamples equally represented (small, medium and large banks).[27] We report descriptive statistics for total assets distribution by terciles in Table 3 below:

Table 3: Descriptive statistics ($1000) on banks total assets by terciles of 2011 asset distribution

This table summarizes banks' total assets descriptive statistics. We use data collected from the Wharton Research Data Service (WRDS). The sample consists of 59,600 bank-year observations on 3,725 banks spanning the period 1996-2011. Based on terciles of the banks' total assets distribution in year 2011, we divide our sample in three subsamples equally represented (small, medium and large banks).

	Obs	Mean	Median	Std. Dev.	Min	Max
Whole sample	59,600	515,316	101,580	1.36E+07	3,650	1.29E+09
Small	20,032	41,459	39,118	20,221.46	3,650	192,886
Medium	20,576	116,284	106,604	50,784.31	7,942	815,892
Large	18,992	1,447,435	327,502	2.41E+07	16,460	1.29E+09

[25] CCyB can be viewed as a contingent claim, i.e., an option on the cycle. To apply option pricing theory to model CCyB, one has to make a different kind of assumptions, in particular, the distributions of the state variables underlying processes (here the GDP growth or the credit-to-GDP gap). One can also model the GDP growth dynamics and use simulation to estimate CCyB. We use instead a scenario analysis in which our representative bank takes action at date 0 in function of the likelihood of a future CCyB activation at date 0 prior to its lending decision. We assign a probability (p_1) to the case with CCyB not activated and $1 - p_1$ to the state with CCyB activated. We obtain an expected value of the capital requirement at date 0 of $a_0 + 2.5\%(1 - p_1)$, (2.5% is the Basel III maximum CCyB level and a_0 is the initial minimum risk-weighted capital ratio). For this characterization, p_1 is a function of macroeconomic conditions. This shifts the bank expected capital minimum requirement level at date 0 but does not affect our overall analysis.

[26] In fact, the Basel I international capital standards were not fully implemented in the US until 1992. In addition, total risk-weighted capital (Tier 1 plus Tier 2) ratios needed for our analysis were not available before 1996.

[27] We recognize that the CCyB requirement per se, is not intended for small banks but for the sake of comprehensiveness, we include them in our study.

We start by calibrating the parameters and the variables appearing in the CCyB (m_a^*) equation. These variables are the bank leverage ($\frac{A}{E}$), loan loss ratio ($\bar{s}_y$), asset risk weight (w) and their cyclical effects. Since we lack granularity to estimate separately bond and asset risk weights, we assign the same risk weight (w) to both of these. We set bond return (γ) at 4%[28], slightly lower than the net return on loan of 5%. We set the minimum unconditional to the cycle capital ratio to a_0= 8% to reflect the fact that under Basel II, banks were subjected to a minimum risk-based capital ratio of 8%.[29]

For each variable and parameter, we compute the sample average and sensitivity to the economic cycle. Using the gross domestic product (GDP) output gap, we then calibrate our model and show the results in Table 4.[30] Formally, we estimate the following regression model for each variable.

$$X_{it} = \alpha + \beta_1(y_t - \bar{y}_t) + \beta_2 z_{it} + \varepsilon_{it} \ , \qquad (13)$$

where $X \in \left\{\frac{A}{E}, w, \bar{s}\right\}$ is the model variable or parameter and β_1 the sensitivity of the variable to the output gap measure. z_{it} are control variables included in the regression.

Table 4: Values of the calibrated parameters

This table summarizes the calibrated values of the bank equity-to-loan ratio (e^L), the bank leverage ($\frac{A}{E}$), the bank total risk-weighted assets density (w), the sensibility of banks leverage to the cycle variable $(\frac{A}{E})_y$, the sensibility of the risk-weighted assets to the business cycle (m_w^L) and the sensibility of the loan loss ratio to the business cycle ($\bar{s}_y$). We use data collected from the Wharton Research Data Service (WRDS). The sample consists of 59,600 bank-year observations on 3,725 banks spanning the period 1996-2011. Based on terciles of the banks' total assets distribution in 2011, we divide our sample in three subsamples equally represented (small, medium and large banks).

Banks	e^L	$\frac{A}{E}$	w	$(\frac{A}{E})_y$	m_w^L	$\bar{s}_y$
Whole sample	0.187	10.157	0.649	6.628	-0.053	-0.075
Small	0.211	9.666	0.625	1.718	0.039	-0.045
Medium	0.181	10.212	0.651	6.678	-0.120	-0.072
Large	0.166	10.615	0.673	11.753	-0.078	-0.108

[28] Our findings are robust to changes in the value of γ.
[29] However, with the countercyclical capital requirement they will incur a cycle-triggered additional capital of 5% (when both the conservative and countercyclical capital buffers are activated).
[30] We obtain the output gap by extracting the cyclical component of GDP growth using the Kalman filter approach.

6.2 Estimation of the required CCyB levels

Recall the equations for the CCyB required level with or without the LCR requirement:

LCR (No) $$m_a^* = arg_{m_a}\left(\lambda_y \frac{e^L}{\lambda} + \lambda\big(m_a(w_L - w_B) - m_w^L + m_w^B + \bar{s}_y\big) = 0\right),$$

LCR (Yes) $$m_a^* = arg_{m_a}\left(\phi_y \frac{e^L}{\phi} + \phi\big(\boldsymbol{m_a w_L} - m_w^L + (aw_B - \gamma)(\xi_y\varphi + \xi\bar{s}_y) + (\boldsymbol{m_a w_B} - m_w^B)\xi\varphi + \bar{s}_y\big) = 0\right).$$

Using the calibrated values reported in Table 4, we show in Table 5 below the required levels m_a^* of the CCyB as a proportion of the output gap.

Table 5: The required levels of the countercyclical capital buffer (CCyB)

This table presents the values of the CCyB (m_a^*) that are necessary to neutralize the cyclical variations in banks capital ratio under various scenarios. The scenarios are the "no liquidity" or "no-LCR" case (first column) and the cases with liquidity requirements (other columns) with different values of the deposit haircut δ (the liquidity weight associated to the deposits) based on the value suggested in the Basel III liquidity coverage ratio (LCR) framework. We use data collected from the Wharton Research Data Service (WRDS). The sample consists of 59,600 bank-year observations on 3,725 banks spanning the period 1996-2011. Based on terciles of the banks' total assets distribution in 2011, we divide our sample in three subsamples equally represented (small, medium and large banks).

	No LCR	δ = 0.03	δ = 0.10	δ = 0.2	δ = 0.3
Whole sample	0.030	0.134	0.114	0.084	0.054
Small	0.011	0.074	0.063	0.044	0.021
Medium	0.037	0.137	0.119	0.092	0.070
Large	0.041	0.189	0.159	0.114	0.074

6.2.1 Analysis of the CCyB in the absence of the LCR requirement

In the first column of Table 5, we report the level of the CCyB (m_a^*) in the absence of the LCR requirement. We provide the required values for different bank sizes (small, medium and large). We estimate m_a^* to be 0.03 for the whole sample. This corresponds to an add-on capital that varies between 0.2% and 0.04% in top of the minimum 8% advocated by the Basel II.[31] We obtain the add-on capital by multiplying the CCyB with the average value of the output gap $(y - \bar{y})$. Therefore, our model implied add-on capital is negligible compared to the 0-2.5% add-on advocated by Basel III. We also document that large banks require higher levels of CCyB (0.04) compared to smaller banks (0.01). This can be

[31] Using a risk-weight value of 0.65 for w and an output gap y that varies between -0.057 and 0.01.

explained by the fact that their risk-weighted assets are more cyclical than those of smaller banks. Our calibration suggests that the add-on capital varies between -0.35% and 0.06%.

6.2.2 Analysis of the CCyB in presence of the LCR requirement

Recall that the liquidity constraint takes the following form:

$$(1 - w_B)B = \delta D - (\rho - \bar{s})L - \gamma B.$$

A key parameter in the liquidity constraint is the deposits haircut (or run-off rate) δ. We compute the CCyB effect for different levels of δ, ranging from 3% to 30%, depending on the bank deposits stability as suggested by the Basel III requirement.[32] The level of the CCyB are substantially higher under the LCR requirement. For example, we obtain a CCyB of 11.4% (first row and third column) for a haircut on deposits of 10% but of 3% in the absence of the LCR requirement. This matches a minimum add-on capital that varies between 0.1% and 1%. There is also a wide variation by bank size since large banks, as financial crises culprits and main targets for regulators to impose CCyB, require higher CCyB requirement varying between 0.24% and 1.4%. This finding suggests that LCR is likely to amplify the cyclical variation in the equity-to-loan ratio and the required level of CCyB. Our finding is close to the 1.4-1.7% of total add-on capital suggested by van Oordt (2018).

We plot in Figure 1 the required minimum capital ratio under Basel II (Min.CAR.Basel.II) with the one with the countercyclical capital buffer (CCyB) in the absence of the liquidity requirement (LCR) (Min.CAR.w/o.LCR) and those in the presence of the LCR requirement (Min.CAR.w.LCR._δ) for two different haircut values on deposits (3% and 30%) for US large banks during the period of 1996 to 2011.

Insert Figure 1 here.

[32] One can interpret this as a haircut on the bank's deposits. Less stable and short-term deposits have a higher haircut since they are more likely to be withdrawn.

7. Why is the CCyB higher under the LCR requirement?

The interrelation between LCR and the capital ratio (due to the relation between the credit and liquidity weights) overshadows the analysis of the LCR impact on the required level of the countercyclical capital measure. To circumvent this, we consider the special case in which we disconnect the credit and liquidity requirements by assuming that bonds are risk-free. Risk-free bonds are fully LCR-eligible since they are assigned a risk weight of zero. Therefore, they do not enter into the capital requirement calculation. We hypothesize that in this case, any difference in CCyB with LCR and CCyB without LCR can be fully attributed to the LCR requirement.

Under the assumption that bonds are risk-free, we rewrite the bank problem as follows:

$$
\begin{gathered}
Max_{L,B}\, \pi = (\rho - s)L + \gamma B \\
s.t \\
prob(E + \pi \leq \; aw_L L) \leq p\,, \\
B \geq \; \delta D - (\rho - \bar{s})L - \gamma B, \\
B + L = D + E.
\end{gathered}
$$

A major difference of this problem with the initial problem is that bonds (B) are absent from the capital requirement equation (see Equation 2). In addition, there is no liquidity weight in front of B value in the third equation since the total amount of bonds is fully LCR-eligible.

<u>Result 5</u>: Assuming that bonds (B) are risk-free, we summarize below the expressions for the required countercyclical capital buffers with and without LCR,

LCR (No) $$m_a^* = \underbrace{-\lambda_y \frac{e^L}{\lambda^2}}_{>0} + \boldsymbol{m_w} - \boldsymbol{\bar{s}_y},$$

LCR (Yes) $$m_a^* = \underbrace{\gamma \xi \bar{s}_y}_{<0} + \boldsymbol{m_w} - \boldsymbol{\bar{s}_y},$$

with $= \frac{1}{(1-\delta+\gamma)}$, $\lambda = \frac{1}{1+\frac{A}{E}\gamma}$ $and\ \lambda_y = \frac{-\frac{A}{E}y\gamma}{(1+\frac{A}{E}\gamma)^2}$; γ is the return on the bond portfolio.

Proof: Insert *Proof 5* here.

Let us look at m_a^*, the optimal CCyB for both regulatory setups (with and without a liquidity requirement). Both expressions contain the term $\boldsymbol{m_w - \bar{s}_y}$. This suggests that the CCyB required level would contain the two main sources of cyclical variations in the equity-to-loan ratio, namely, the sensitivity of risk-weighted to the business cycle (m_w^L) and the loan loss rate sensitivity to the cycle ($\bar{s}_y$). Both expressions (with and without LCR) differ by two terms ($-\lambda_y \frac{e^L}{\lambda^2}$ $and\ \gamma\xi\bar{s}_y$) that are added to the common term. The first one is positive while the second one negative. Therefore, CCyB in the absence of LCR is higher than CCyB in the presence of LCR. This surprising finding suggests that the amplification role of the LCR requirement is attributed to the cyclical behavior in the liquidity weights associated with risky bonds. We conclude that the most important determinant of the LCR impact on the CCyB requirement comes from the risky bonds "risk-liquidity" trade-off imbedded in the LCR requirement. Risky bonds liquidity weights are likely to be reduced in recessions, putting pressure on banks to invest more in liquid assets. An explanation of this "risk-liquidity" trade-off stems from the fact that credit risk affects risky bonds liquidity weights. These weights diminish during recessions, forcing banks to improve their liquidity position. This reduces banks future expected earnings that would be retained to satisfy capital requirements.

8. Conclusion, policy implications and future research

It was not until the Global Financial Crisis (GFC) that the regulatory debate over the mitigation of bank capital procyclicality resurfaced with much fanfare. Many studies have analyzed the level and operationalization of the Basel III macroprudential countercyclical capital buffers (CCyB). The CCyB main objective is to incentivize banks to increase their capital buffers through the cycle, with a double goal of reducing excessive credit growth and building the necessary buffers to cope well in future downturns.

However, most of the existing studies addressing the issue focus on the regulatory minimum capital requirement instead of bank actual capital ratios. Given that banks largely adjust towards their internal capital ratio, we explicitly model the cyclical variations in bank capital ratios and derive the required optimal countercyclical measure that mitigate bank capital ratio cyclicality. Since Basel III new liquidity rules are also jointly introduced with CCyB, we provide evidence that they are also procyclical and amplify the cyclical variations in US banks capital ratios during 1996 to 2011. We uncover and explain the amplification effect stemming from the trade-off between asset risk and liquidity. Banks trade-off the net profitability between returns from risky assets and their foregone risk-weights in terms of the contribution in meeting the liquidity coverage ratio (LCR) requirement.

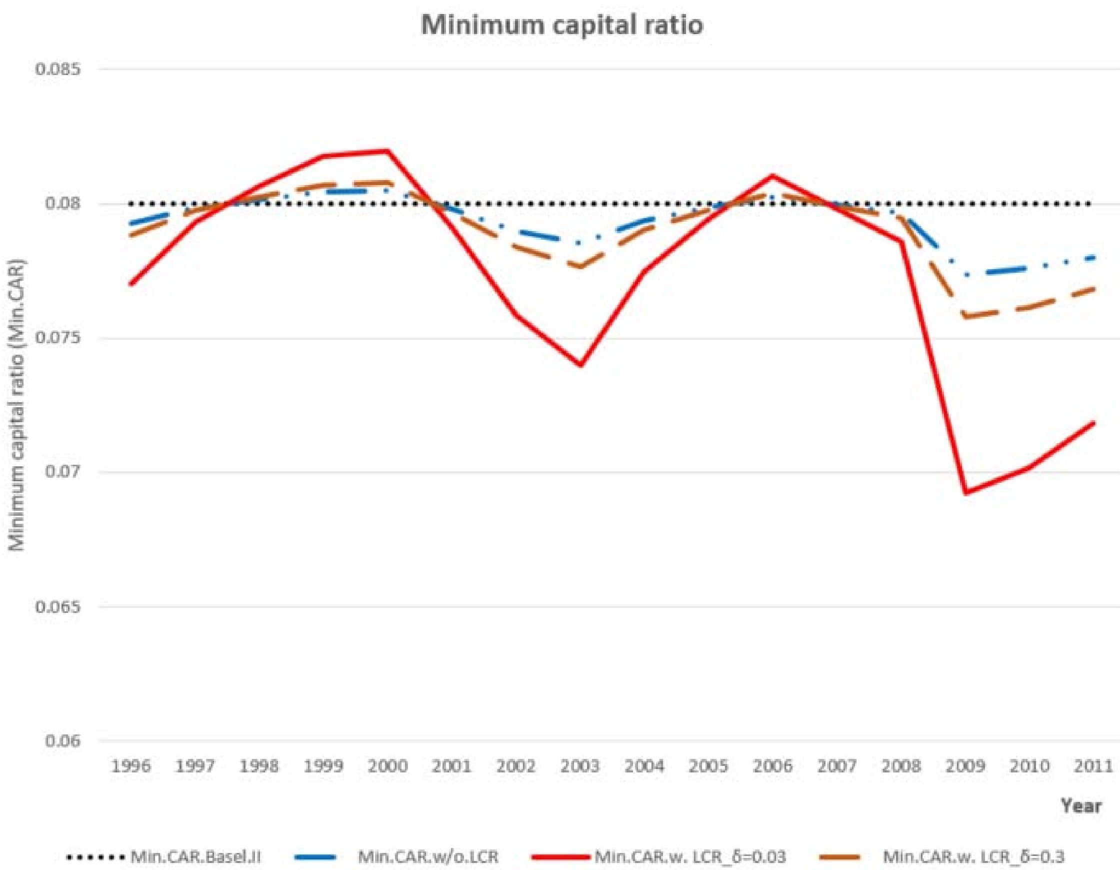
Considering the policy implications of this paper, we should : 1- account for the potential effects of LCR when designing CCyB; 2- relax the LCR requirement during downturns or set an countercyclical LCR requirement to contain LCR cyclical variations and to alleviate LCR potential effects on the cyclical variations in bank equity-to-loan ratios, and 3- recognize the risk-liquidity trade-off that comes with the LCR requirement that impacts the CCyB level.

Our study is most fitting in light of the ongoing COVID-19 pandemic. Following the COVID-19 outbreak, given that banks hold higher levels of common equity capital in early 2020 than those pre-GFC, the USA, Canada and many countries around the world have cut their CCyB requirements, providing banks with the capital to support lending and the banking industry to preserve and boost capital to weather well the current pandemic crisis. This study may be extended in various ways. The analysis of cyclical behavior being dynamic in nature, the paper would benefit from a fully dynamic framework. One can incorporate an analysis of the Basel III liquidity measure such as the net stable funding ratio (NSFR) and its effects on the optimal CCyB into a dynamic framework.[33] It would also be possible to model explicitly the conservation capital buffer (CCB) requirement by constraining the bank year-end income distribution. The combined two requirements (CBB and CCyB) will go tough on undercapitalized banks but will provide ample buffers for banks to expand their balance sheets and stimulate the economy during a recession. By interacting and stabilizing macroeconomic variables, CCyB affects business cycle dynamics. Therefore, it becomes desirable to account for these in designing CCyB. Last but not least, it would be interesting to model the countercyclical capital buffer as a put option on the aggregate macroeconomic variables.

[33] However, during periods of severe and extreme stress, banks are likely to breach the HQLA floor. Unfortunately, the extent to which the HQLA floor will be relaxed by regulators is unknown. As witnessed during the 2020 COVID-19 outbreak, central banks and regulatory bodies around the globe provide guidance on the specific application of the HQLA.

Figure 1. Minimum capital ratio: The case of large banks

This figure plots the required level of the minimum capital ratio from 1996 to 2011 for US large banks. Basel II minimum capital ratio (Min.CAR.Basel.II) is the Basel II minimum capital ratio of 8%. Min.CAR.w/o.LCR denotes the Basel II 8% limit augmented with the countercyclically buffer CCyB in the absence of the Basel LCR requirement while Min.CAR.w.LCR_δ=0.03 and Min.CAR.w.LCR_δ=0.3 designate the Basel II 8% augmented with the minimum required under the LCR requirement for an average haircut rate on deposits equal to 3% and 30% respectively.



Appendix. Proofs of results

Proof 1

Let us recall that our objective is to determine the level of capital ratio that solve the bank problem. We justify in the main text that the problem can be reduced to the capital and balance sheet constraints given a higher preference of loans (L) to bonds (B) in risk-adjusted terms. The capital constraint is expressed as follows:

$$prob(E + \pi \leq \ a(w_L L + w_B B)) \leq p.$$

Replacing $\pi_1 = (\rho - s)L + \gamma B$ in the previous equation gives:

$$prob(E + (\rho - s)L + \gamma B \ \ \leq \ a(w_L L + w_B B)) \leq p.$$

Scaling by loans (L), we obtain:

$$prob(\frac{E}{L} + (\rho - s) + \gamma \frac{B}{L} \ \ \leq \ a(w_L + w_B \frac{B}{L})) \leq p,$$

and rewriting the last expression and noting $e^L = \frac{E}{L}$ and $b^L = \frac{B}{L}$, we obtain:

$$1 - prob(s \leq e^L + \rho + \gamma b^L - aw_L - aw_B b^L) \leq \ p.$$

Since s follows a distribution with a cumulative function F_s (with mean $\bar{s}$ and standard deviation of σ), we get:

$$1 - p \leq F_s\left(\frac{e^L + \rho + \gamma b^L - aw_L - aw_B b^L - \bar{s}}{\sigma}\right),$$

$$\sigma F_s^{-1}(1 - p) \leq e^L + \rho + (\gamma - aw_B)b^L - aw_L - \bar{s}.$$

By writing $\alpha = \sigma F_s^{-1}(1 - p)$, we have:

$$e^L \geq (\alpha + a(w_L + w_B b^L) - \gamma b^L - (\rho - \bar{s}))\ .$$

The only unknown from the previous relation, the bonds-to-loan ratio b^L can be expressed in terms of equity-to-loan ratio as follows:

$$b^L = \frac{A-L}{L} = \frac{A}{E}\frac{E}{L} - 1 = \frac{A}{E}e^L - 1.$$

By replacing the bonds-to-loan ratio b^L in our main equation and factoring e^L, we get the equilibrium level of capital ratio e^L that depends on exogenous parameters.

$$e^L \geq \lambda(\alpha + a(w_L - w_B) + \gamma - (\rho - \bar{s})),$$

with $\lambda = \frac{1}{1-\frac{A}{E}(aw_B-\gamma)}$.

Proof 2

Recall the binding bank optimal equity-to-loan ratio:

$$e^L = \lambda(\alpha + a(w_L - w_B) + \gamma - (\rho - \bar{s})).$$

We obtain the derivative of e^L with respect to the cycle called e_y^L as follows:

$$e_y^L = \lambda_y(\alpha + w_L - w_B + \gamma - (\rho - \bar{s})) + \lambda(a(w_y^L - w_y^B) + \bar{s}_y)$$

$$e_y^L = \lambda_y(\alpha + w_L - w_B + \gamma - (\rho - \bar{s})) + \lambda(-m_w^L + m_w^B + \bar{s}_y)$$

$$e_y^L = \lambda_y \frac{e^L}{\lambda} + \lambda\left(-m_w^L + m_w^B + \bar{s}_y\right),$$

with, $\lambda_y = \frac{\frac{A}{E_y}(aw_B-\gamma)+\frac{A}{E}(-m_w^B)}{(1-\frac{A}{E}(aw_B-\gamma))^2}$ and $\lambda = \frac{1}{1-\frac{A}{E}(aw_B-\gamma)}$.

Proof 3

From $e^L = \lambda(\alpha + a(w_L - w_B) + \gamma - (\rho - \bar{s}))$, we obtain the derivative of the optimal equity-to-loan ratio e^L with respect to the cycle as follows:

$$e_y^L = \lambda_y\left(\alpha + w_L - w_B + \gamma - (\rho - \bar{s})\right) + \lambda\left(a_y(w_L - w_B) + a\left(w_y^L - w_y^B\right) + \bar{s}_y\right).$$

Replacing the equation of the CCyB: $a(y) = a_0 + m_a(y - \bar{y})$, we obtain:

$$e_y^L = \lambda_y\left(\alpha + w_L - w_B + \gamma - (\rho - \bar{s})\right) + \lambda\left(m_a(w_L - w_B) - m_w^L + m_w^B + \bar{s}_y\right),$$

$$e_y^L = \lambda_y \frac{e^L}{\lambda} + \lambda\big(m_a(w_L - w_B) - m_w^L + m_w^B + \bar{s}_y\big),$$

with, $\lambda_y = \frac{\frac{A}{E_y}(aw_B-\gamma)+\frac{A}{E}(m_a w_B - m_w^B)}{(1-\frac{A}{E}(aw_B-\gamma))^2}$ and $\lambda = \frac{1}{1-\frac{A}{E}(aw_B-\gamma)}$.

Proof 4

Replacing the balance sheet constraint ($D = B + L - E$) in the LCR constraint yields:

$$(1 - w_B)B = \delta D - (\rho - \bar{s})L - \gamma B \quad (10)$$

$$(1 - w_B)B = \delta(B + L - E) - (\rho - \bar{s})L - \gamma B$$

$$(1 - w_B - \delta + \gamma)B = \big(\delta - (\rho - \bar{s})\big)L - \delta E\ ,$$

$$b^L = \frac{\big(\delta - (\rho - \bar{s})\big) - \delta e^L}{(1 - w_B - \delta + \gamma)},$$

$$b^L = \xi(\varphi - \delta e^L).$$

$\xi = \frac{1}{(1-w_B-\delta+\gamma)}$ and $\varphi = \delta - (\rho - \bar{s})$.

Recall $e^L = (\alpha + a(w_L + w_B b^L) - \gamma b^L - (\rho - \bar{s}))$.

The only unknown from the previous relation is the bonds-to-loan ratio b^L.

Replacing the bonds-to-loan ratio b^L in our main equation and factoring e^L, give us the equilibrium level of capital ratio e^L that depends on exogenous parameters.

$$e^L \geq \alpha + aw_L + (aw_B - \gamma)\xi(\varphi - \delta e^L) - (\rho - \bar{s})),$$

$$e^L \geq \phi\big(\alpha + aw_L + \xi\varphi(aw_B - \gamma) + \gamma - (\rho - \bar{s})\big),$$

with $\phi = \frac{1}{1+\xi\delta(aw_B-\gamma)}$.

Proof 5

Assuming that the bonds are risk-free, we solve the following bank capital constrained problem:

$$prob(E+\pi \leq \ aw_L L) \ \leq p.$$

Replacing $\pi = (\rho - s)L + \gamma B$ and using an approach similar to the one used for Proof 1, we get:

$$e^L \geq \lambda(\alpha - \rho - \gamma + aw_L + \bar{s}\,),$$

with $\lambda = \frac{1}{1-\frac{A}{E}(-\gamma)}$ and $\alpha = \sigma F_s^{-1}(1-p)$.

Based on the equilibrium equity-to-loan ratio, we obtain the cyclical behavior of the capital ratio and the required level of CCyB as follows:

- *Without the LCR requirement*

$$e^L \geq \lambda(\alpha - \rho - \gamma + aw_L + \bar{s}\,)$$

$$e_y^L = \lambda_y \frac{e^L}{\lambda} + \lambda\big(-m_w + m_a + \bar{s}_y\big),$$

with, $\lambda = \frac{1}{1+\frac{A}{E}\gamma}$ and $\lambda_y = \frac{-\frac{A}{E}y\gamma}{(1+\frac{A}{E}\gamma)^2}$.

$$m_a^* = -\lambda_y \frac{e^L}{\lambda^2} + m_w - \bar{s}_y.$$

- *With the LCR requirement*

The LCR requirement under the assumption that 100% of bonds are risk-free goes as follows.

$$B \geq \ \delta D - (\rho - \bar{s})L - \gamma B\,.$$

Assuming that the constraint binds, we get:

$$B = \ \delta(B + L - E) - (\rho - \bar{s})L - \gamma B,$$

$$b^L = \frac{\big(\delta - (\rho - \bar{s})\big) - \delta e^L}{(1 - \delta + \gamma)}$$

$b^L = \xi(\varphi - \delta e^L)$,

$\xi = \frac{1}{(1-\delta+\gamma)}$ and $\varphi = \delta - (\rho - \bar{s})$.

Replacing b^L in the equity-to-loan equilibrium equation, we get:

$$e^L \geq \alpha + aw_L - \gamma b^L - (\rho - \bar{s}))$$

$$e^L \geq \alpha + aw_L - \gamma\xi(\varphi - \delta e^L) - (\rho - \bar{s}))$$

$$e^L(1 - \gamma\xi\delta) \geq \alpha + aw_L - \gamma\xi\big(\delta - (\rho - \bar{s})\big) - (\rho - \bar{s}))$$

$$e^L \geq \frac{1}{(1-\gamma\xi\delta)}(\alpha + aw_L - \gamma\xi\big(\delta - (\rho - \bar{s})\big) - (\rho - \bar{s}))\ ),$$

$$\text{or} \quad e^L \geq \frac{1}{(1-\gamma\xi\delta)}\big(\alpha + aw_L - \gamma\xi\delta + (\gamma\xi - 1)(\rho - \bar{s})\big).$$

Zooming on the cyclical behavior, we have:

$$e^L \geq \kappa\big(\alpha + aw_L - \gamma\xi\delta + (\gamma\xi - 1)(\rho - \bar{s})\big),$$

with $\kappa = \frac{1}{(1-\gamma\xi\delta)}$,

$$e_y^L = \kappa_y \frac{e^L}{\kappa} + \kappa\big(-m_w + m_a + (1-\gamma\xi)\bar{s}_y\big),$$

and $\kappa_y = 0$.

Therefore, e_y^L reduces to: $e_y^L = \kappa\big(-m_w + m_a + (1-\gamma\xi)\bar{s}_y\big)$.

The required equilibrium CCyB to annul the cyclical variation in e_y^L is:

$$m_a^* = m_w - (1-\gamma\xi)\bar{s}_y.$$

References

Albertazzi, U., Gambacorta, L., 2009. Bank profitability and the business cycle. *Journal of Financial Stability*, 5 (4), 393–409.

Arbatli-Saxegaard, E.C. and Muneer, M.A., 2020. The countercyclical capital buffer: A cross-country overview of policy frameworks, Norges Bank Staff Memo No. 6.

Auerand, R., Ongena, S., 2016. The countercyclical capital buffer and the composition of bank lending. *BIS Working Papers* 593.

Ayuso, J., Pérez, D., Saurina, J., 2004. Are capital buffers procyclical? Evidence from Spanish panel data. *Journal of Financial Intermediation*, 13 (2), 249–264.

BCBS, 2011. Basel III: A global regulatory framework for more resilient banks and banking systems. *Bank for International Settlements*.

BCBS, 2013. Basel III: The liquidity coverage ratio and liquidity risk monitoring tools. *Bank for International Settlements.*

Behn, M., Haselmann, R., Wachtel, P., 2016a. Procyclical capital regulation and lending. *The Journal of Finance*, 71 (2), 919–956.

Behn, M., Haselmann, R. F., Vig, V., 2016b. The limits of model-based regulation. *European Central Bank (ECB) Working Paper*, No. 1928.

Bekiros, S., Nilavongse, R., Uddin, G. S., 2018. Bank capital shocks and countercyclical requirements: Implications for banking stability and welfare. *Journal of Economic Dynamics & Control*, 93 (1), 315–331.

Benes, J., Kumhof, M., 2015. Risky bank lending and countercyclical capital buffers. *Journal of Economic Dynamics & Control,* 58, 58–80.

Berrospide, J., 2013. Bank liquidity hoarding and the financial crises: An empirical evaluation. *Finance and Economics Discussion Series, Federal Reserve Board, Washington, D.C.*

BIS, 2018. Liquidity coverage ratio (LCR): Executive Summary. *Bank for International Settlements.*

Blum, J., Hellwig, M., 1995. The macroeconomic implications of capital adequacy requirements for banks. *European Economic Review,* 39 (3), 739–749.

Bolt, W., De Haan, L., Hoeberichts, M., Van Oordt, M., Swank, J., 2012. Bank profitability during recessions. *Journal of Banking and Finance,* 36 (9), 2552– 2564.

Bonner, C., Eijffinger, S. C., 2016. The impact of liquidity regulation on bank intermediation. *Review of Finance,* 20 (5), 1945–1979.

Borio, C., Drehmann, M., Gambacorta, L., Jiménez, G., Trucharte, C., 2010. Countercyclical capital buffers: Exploring options. *BIS Working Papers* 317.

Brave, S., Lopez, J., 2019. Calibrating macroprudential policy to forecasts of financial stability. *International Journal of Central Banking,* 15 (1), 3-59.

BIS-FSI Connect, 2019. The capital buffers in Basel III – Executive Summary.

Calomiris, C., Heider, F., Hoerova, M., 2016. A theory of bank liquidity requirements. Columbia Business School Research Paper No. 14-39.

Cornett, M. M., Minnick, K., Schorno, P. J., Tehranian, H., 2020. An examination of bank behavior around Federal Reserve stress tests. *Journal of Financial Intermediation*, *41*, 100789.

De Nicolò, G., Gamba, A., Lucchetta, M., 2014. Microprudential regulation in a dynamic model of banking. *Review of Financial Studies*, 27 (7), 2097–2138.

Drehmann, M., Borio, C., Tsatsaronis, K., 2011. Anchoring countercyclical capital buffers: The role of credit aggregates. *International Journal of Central Banking*, 7 (4), 189–240.

Drehmann, M., Juselius, M., 2013. Evaluating early warning indicators of banking crises: Satisfying policy requirements. *Bank for International Settlements Working Papers 421*.

Drehmann, M., Yetman, J., 2020. Which credit gap is better at predicting financial crises? A comparison of univariate filters (No. 878). *Bank for International Settlements*.

Drehmann, M., Farag, M., Tarashev, N. and Tsatsaronis, K., 2020. Buffering Covid-19 losses-the role of prudential policy (No. 9). *Bank for International Settlements*.

Edge, R. M., Meisenzahl, R. R., 2011. The unreliability of credit-to-GDP ratio gaps in real time: Implications for countercyclical capital buffers. *International Journal of Central Banking*, 7 (4), 261-298.

Estrella, A., 2004. The cyclical behavior of optimal bank capital. *Journal of Banking and Finance*, 28 (6), 1469–1498.

Francis, W. B., Osborne, M., 2012. Capital requirements and bank behavior in the UK: Are there lessons for international capital standards? *Journal of Banking and Finance,* 36 (3), 803–816.

Guidara, A., Lai, V.S., Soumaré, I., Tchana Tchana, F., 2013. Banks' capital buffer, risk and performance in the Canadian banking system: Impact of business cycles and regulatory changes. *Journal of Banking and Finance,* 37 (9), 3373–3387.

Heid, F., 2007. The cyclical effects of the Basel II capital requirements. *Journal of Banking and Finance,* 31 (12), 3885–3900.

Hugonnier, J., Morellec, E., 2017. Bank capital, liquid reserves, and insolvency risk. *Journal of Financial Economics*, 125 (2), 266–285.

Jarrow, R., 2013. A leverage ratio rule for capital adequacy. *Journal of Banking and Finance*, 37(3), 973-976.

Jiménez, G., Ongena, S., Peydr, J. L., Saurina, J., 2017. Macroprudential policy, countercyclical bank capital buffers, and credit supply: Evidence from the Spanish dynamic provisioning experiments. *Journal of Political Economy,* 125 (6), 2126–2177.

Jokipii, T., Milne, A., 2008. The cyclical behaviour of European bank capital buffers. *Journal of Banking and Finance*, 32 (8), 1440–1451.

Jokipii, T., Nyffeler, R., Riederer, S., 2020. Exploring BIS credit-to-GDP gap critiques: The Swiss case (No. 2020-19).

Jokivuolle, E., Kiema, I., Vesala, T., 2014. Why do we need countercyclical capital requirement? *Journal of Financial Services Research*, 46 (1), 55–76.

Karmakar, S., 2016. Macroprudential regulation and macroeconomic activity. *Journal of Financial Stability,* 25, 166–178.

Kashyap, A. K., Stein, J., 2004. Cyclical implications of the Basel II capital standard. *Economic Perspectives, Federal Reserve Bank of Chicago*, 19–31.

Koch, C., Richardson, G. and Van Horn, P., 2020. Countercyclical capital buffers: A cautionary tale (No. w26710). *National Bureau of Economic Research*.

Lewrick, U., Schmieder, C., Sobrun, J. and Takats, E., 2020. Releasing bank buffers to cushion the crisis-a quantitative assessment (No. 11). *Bank for International Settlements*.

Morgan, P. J., Regis, P. J., Salike, N., 2019. LTV policy as a macroprudential tool and its effects on residential mortgage loans. *Journal of Financial Intermediation,* 37, 89-103.

Occhino, F., 2018. Are the new Basel III capital buffers countercyclical? Exploring the option of a rule-based countercyclical buffer, *Economic Commentary Federal Reserve Bank of Cleverland*, 3, pp. 1-6.

Plosser, M. C., Santos, J. A., 2018. Banks' incentives and inconsistent risk models. *The Review of Financial Studies*, 31(6), 2080-2112.

Repullo, R., Saurina, J., Trucharte, C., 2010. Mitigating the procyclicality of Basel II. *Economic Policy*, 25 (64), 659–702.

Repullo, R., Saurina, J., 2011. The countercyclical capital buffer of Basel III: A critical assessment.

Rogers, C., 2018. The lessons of Basel 3 and the path ahead for Canada. *RBC Capital Markets Canadian Bank CEO Conference*.

Schneider, T. I., Strahan, P. E., Yang, J., 2020. Bank stress testing: Public interest or regulatory capture? (No. w26887). *National Bureau of Economic Research*.

van Oordt, M. R. C., 2018. Calibrating the magnitude of the countercyclical capital buffer using market-based stress tests. *Bank of Canada*, *Staff Working Papers*, 54.