Bank Countercyclical Capital Buffer under the Liquidity Coverage Ratio Regulation

December 2022

We acknowledge the financial support from the Autorité des Marchés Financiers (AMF) (Education and Good Governance Fund Contract SC-1968), the AMF Integrated Risk Management of Financial Institutions Research Fund, the Conrad Leblanc Fund, the Social Sciences and Humanities Research Council of Canada and the "Fond de démarrage" from the University of Sherbrooke. We appreciate the insights from Michael Kiley from the Federal Reserve Bank and Maarten R.C. van Oordt from the Bank of Canada, and Magdalena Pisa from Otto Beisheim School of Management. We thank Alain Bélanger, Claudia Champagne, Frank Coggins, Georges Dionne, Jean-Marie Gagnon and participants at the 52nd Canadian Economic Association conference at McGill University, the 2021 International Conference of the French Finance Association (AFFI) and the 2021 Financial Management Association (FMA) Annual Meeting for their valuable comments.

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Abstract

We study the interrelationship between the Basel III countercyclical capital buffer (CCyB) and the liquidity coverage ratio (LCR) requirement. 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 show that LCR affects the CCyB required level to dampen the cyclicality in bank actual capital ratios. We find that an add-on of 5% of the output gap changes range is sufficient to mitigate U.S. bank capital ratios cyclicality. 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 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 equity capital post-GFC than pre-GFC. This enables the USA, Canada and many countries around the world to cut their CCyB requirements, supplying the banking industry with capital not only to support lending vital to the real economy but also to preserve and boost capital to weather banks robustly the pandemic crisis.

JEL classification: E32; E44; G21; G28

Keywords: Basel III, Capital ratios, Liquidity coverage ratio, 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. Prominently, to address the cyclical variation in banks' capital and its negative impact on lending, a countercyclical minimum capital buffer (CCyB) 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. (2016) echo this issue by showing how during the GFC, following a half percentage points increase in capital requirement (i.e., capital charge), German banks reduced their lending activities by 2.1 to 3.9 percentage points. 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 increment 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 providing banks with usable 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 enables the smoothing 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 bank reported (and observed) capital cyclicality issues. To this end, we develop a partial equilibrium model to endogenize the bank capital adjustment behavior and to quantify the required CCyB level to reduce or to nullify the cyclical variations in the banks' equity-to-loan ratios.

The mechanism that drives the bank capital cyclical variations goes as follows. Let us subject banks to a minimum capital ratio of 8% of their risk-weighted assets. Since the asset risk charge depends on the borrower's default probability, it varies with the

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[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). When the economy expands, being less constrained by regulatory limit of 8%, a 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 risks, 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.

[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.

business cycle. Banks find it is much more demanding to meet capital charges in recessions than in expansions.[3] When the economy expands, being less constrained by the regulatory minimum, the bank level of capital increases from both higher retained profits and lowered asset risks. When a recession hits the economy, with less profits and elevated asset risk, most banks accumulated capital buffers deplete quickly. Banks are left with an inevitable option of raising fresh external capital and/or 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 the banks' ability to lend in bad times, the minimum capital requirement sensitivity to the business cycles and the consequent bank capital adjustments are of paramount importance in bank capital regulation.

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 variations of banks' capital ratios, the Basel Committee on Bank Supervision (BCBS) has released a document to provide guidelines for designing the countercyclical capital buffer (CCyB) measures (BCBS, 2011). Some countries with large banking systems have so far activated the Basel III CCyB. The U.S. has implemented the CCyB on October 14, 2016.[5] Following concerns about excessive credit growth, several countries in Europe having 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.[7]

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,

[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 .
[7] For instance, Auerand and Ongena (2016) find that the CCyB implemented in 2012 to curb banks' mortgage lending in Switzerland has affected banks' asset composition by shifting their lending to small firms loans (unconstrained by the regulation in question).

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., 2016). With objectives clearly different from ours, studies such as those by De Nicolò et al. (2014) and Hugonnier and Morellec (2017) among others, investigated bank adjustments of capital and liquidity due to the joint regulation of these risks. 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 study potential ramifications of CCyB (or some of its alternatives[8]) on some macroeconomic variables and CCyB welfare effects.[9]

Unlike all of these papers, we employ a partial equilibrium model that enables us to quantify both the cyclical variation in banks' actual capital ratios and the countercyclical capital buffer that is necessary to mitigate variations of bank capital ratio cyclicality.[10] For simplicity, we extend a model by Heid (2007) to capture key stylized facts on banks' capital adjustment behavior, namely 1-the presence capital buffers that banks hold on top of the minimum capital requirement, 2-the existence of banks internal capital targets that are different from the regulatory minimum, and 3-the explicit analysis of cyclical variations in bank assets and profitability.[11]

In a novel fashion, we account for the Basel III new requirement by modelling interactions between Basel III liquidity rules and the CCyB requirement. We rely on the Basel definition 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

[8] 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.

[9] 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. In particular, Karmakar (2016) develops a dynamic stochastic general equilibrium (DSGE) model with financial intermediation activities and shows that CCyB are useful in reducing volatility (macro variables and shocks) and raising economic welfare. Furthermore, Benes and Kumhof (2015) show that CCyB not only increases welfare but also reduces the need of implementing others countercyclical policy rates. By means of a DSGE model with a banking sector, Bekiros et al. (2018) study banks' reaction to different countercyclical buffers (CCyB) after shocks to banks' capital. They find that bank CCyB reacting to the deviation of credit from its steady state level is most powerful in enhancing the banking stability and provides the highest welfare against other measures based on the credit to output ratio or credit growth.

[10] Indeed, Francis and Osborne (2012) show that the bank capital requirements (including firm-specific and time-varying public supervisory add-ons) affect bank desired capital ratios, and the consequent 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.

[11] Heid (2007), among others, shows that capital buffers can mitigate the cyclical behavior of banks' capital ratios. 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.

requirements and, as a result, the CCyB level. LCR is expected to affect the effectiveness of the countercyclical measure in various ways. HQLA, the numerator of LCR is obtained as a 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 the risk of an asset, 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 drive bank portfolio adjustments through the cycle. Furthermore, we expect LCR cyclicality effects to be reinforced by the run-on wholesale funds in recessions causing the denominator of LCR to become bigger. Therefore, banks adjust by hoarding liquid assets (the numerator of LCR) as experienced during the GFC (see e.g., Berrospide, 2013) or by reducing their deposit outflows by investing in stable funding. The liquidity requirement when it is binding strain banks' future profits. As banks rely on profits to meet minimum capital requirements, changes in the composition of HQLA will affect bank future profitability, and consequently their ability in adjusting adequately capital ratios and lending decisions (see for instance, Bonner and Eijffinger, 2016).

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

Towards this end, after deriving a bank optimal countercyclical capital buffer (CCyB) model, we calibrate it using an extensive database on 3,725 American (U.S.) banks spanning the period 1996-2011 totalizing 59,600 bank year observations.[12] Since banks' size affects their risk-taking behavior, we divide our sample in three subsamples of equal size (small, medium and large banks), using the distribution of banks' asset in year 2011. Our calibration exercise suggests that an add-on of 5% of the output gap

[12] 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.

changes “range” above the minimum capital ratio of 8% is sufficient to mitigate the cyclical changes in banks’ actual capital ratio. Since we have experienced an output gap drop of 6% during the GFC (where no liquidity rule was in effect), our finding suggests that dropping from 8% to 7% in the minimum Basel capital ratio requirement would have been sufficiently accommodative for banks throughout GFC. A recent study by Occhino (2018) advocates a 1% reduction in the Tier 1 capital ratio for U.S. banks during the GFC.

Following the COVID-19 outbreak, Basel III capital and liquidity buffers were relaxed. Dursun-de Neef et al. (2022) imply that the release of the CCyBs was effective in promoting European bank lending whereas Berrospide et al. (2021) and Beck et al. (2021) find that ample capital buffers at the US and EU banks went unused during the COVID-19 pandemic. Therefore, the key takeaways from this paper which have materially manifested in the aftermath of the COVID-19 pandemic are as follows: 1- policymakers need to account for the potential effect of LCR when designing CCyB, 2- the CCyB effect that is needed to mitigate the cyclical variation in banks’ actual capital ratio varies significantly with bank’s size precluding one-size-fits-all approach in the CCyB design, 3- relaxing the LCR requirement during downturns or setting countercyclical LCR requirement might be desirable to contain the cyclical variations in LCR and its potential effects on the cyclical variations of bank capital ratios, and 4- the LCR impact on 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 (CCyB) 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 (2020) 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 (2020) finds that a CCyB ranging from 1.4 to 1.7 per cent of bank total assets is necessary. We share with van Oordt (2020) the same approach of working directly with bank actual capital. However, we differ from van Oordt (2020) because we not only explicitly model 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 the 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 correct anchor to use for activating CCyB. Their analysis reveals that the CCyB activation by U.S. policymakers at the end of 2016 was inappropriate.[13]

The rest of the paper is structured as follows. We present an overview of the Basel III CCyB in Section 1 and describe our baseline model in Section 2. In Section 3, we study the equilibrium of our focal bank equity-to-loan ratio and derive the level of CCyB that is required to annul its cyclical behavior. To determine the CCyB magnitude, we conduct a calibration study in Section 4. We extend the model to include the Basel III short-term liquidity rule and risky bonds in Section 5 and 6. In Section 7, we analyze LCR effects on CCyB and we conclude and offer policy implications in Section 8.

1- An overview of the Basel III CCyB

The Basel III macroprudential CCyB aims at increasing both the quantity and the quality of bank capital during periods of expansion by increasing the minimum capital ratio by increments up to 2.5% (BCBS, 2011).

Once the CCyB requirement is activated, the CCyB framework requires banks 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 BIS (Bank for International Settlements) suggest that the CCyB should be activated when the credit-to-GDP ratio exceeds 2%. The buffer is expected to increase gradually to reach its maximum of 2.5% when the credit-to-GDP attain a value of 10%. To get the intuition behind the

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

countercyclical buffer, let us consider a bank with the following balance sheet:

Table 1: The bank balance sheet at date 0 ($)

Assets	Liabilities and Equity
Bonds: 20	Deposits: 96.5
Loans: 80	Equity/Capital: 3.5

Assume the risk weights associated to bonds and loans to be 0% and 50% respectively. A bank with the balance sheet described in Table 1 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). Assume now that we are at the peak phase of a 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 required to $4.2 ($3.2 + $1). Suppose 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).[14] With the CCyB in effect, the bank has maintained a minimum capital of $4.2. Therefore, it will look for an additional capital of $0.28. On the contrary, if the CCyB were not activated, the banks would have been operating with a capital of $3.2 and they would need 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 the periods of excessive growth, policy-makers aim to ease strain on bank capital when the economy enters a recession as it was the case in 2020, right after the COVID-19 outbreak.

2. The model set-up

We employ a partial equilibrium banking model built on the framework by Heid (2007). There are three agents in the model: 1) a representative risk-neutral bank, 2) a depositor with deep pocket and 3) a regulator. This type of model enables us to derive explicitly endogenous banks' capital buffers consistent with the levels of capital buffer documented in the empirical literature.[15]

[14] $56 is the RWA associated to the new risk-weight of 70% for loans.
[15] Most of the theoretical literature on bank capital assumes that banks hold no capital buffer since capital is costly.

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.[16] By zooming on one period, we focus on short-term adjustments[17] in the banks' balance sheet to meet changes in regulation.

Table 2: The bank balance sheet at date 0

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

The risk-neutral representative banker starts with the balance sheet depicted in Table 2. He owns initial equity E and collects deposits D. Deposits (D) are insured (with no premium cost[18]) by the regulator and assumed to earn zero (0) return. Collected funds ($E + D$) are invested in risky loans (L) and riskless bonds (B). We assume that loans are more attractive than bonds in risk-adjusted terms. The bank decision at date 0 is to choose an optimal loan level under constraints fixed by the regulator.[19]

2.2 The regulator

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

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

Retaining all the profits to meet capital requirements, the numerator of the ratio on the left-hand side of Equation (1) is the bank total capital at date 1. Since bonds B are riskless with a risk-weighted of zero ($w_B = 0$), the denominator ($w_L L$) is the risk-

[16] Using one-period model can be justified by Estrella et al. (2004) who find that 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.

[17] Accordingly, time consuming operation such as equity issuing are precluded but can be accounted for in a dynamic framework.

[18] This assumption could be replaced by a flat rate on deposits without any substantial effect on the model results. Alternatively, returns on loans and bonds may be viewed as net of interest expenses. We consider the latter case in the simulation framework.

[19] 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.

weighted total assets. Therefore, the regulator expects the bank to maintain at date 1 a minimum ratio of capital of a (consisting of initial equity E plus bank total profit, i.e., $(E + \pi)$ to risk-weighted assets $(w_L L)$).

2.3 The bank objective function

Our representative risk-neutral bank maximizes its expected date 1 profit (π) under the regulatory capital constraint at date 0. We formulate the bank maximisation problem as follows:

$$Max_{L,B}\, \pi = (\rho - s)L + rB \quad (2.a) \qquad\qquad (2)$$
$$s.t$$
$$prob\left(\frac{E+\pi}{w_L} \leq a\right) \leq p, \quad (2.b)$$
$$B + L = D + E \qquad (2.c)$$

The bank total profit at date 1, (π), is generated from loans with net return of $(\rho - s)$ and bonds with return r.[20] 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 then driven by s[21] having an expected value of $\bar{s}$ and a volatility of σ. Its standardized value[22] is assumed to follow a probability distribution with a cumulative function *F*.

Under a value at risk (VaR) framework, the capital constraint Equation (2.b) makes its portfolio mix choice ($A = L + B$) so that the risk of falling short of the minimal capital requirement (at date 1) is equal or lower than *p*. The ex-ante choice of the probability *p* is assumed exogenous and depends on the bank's perceived costs of falling below the minimum requirement at date 1. These costs are agency and regulatory ones and includes the loss of charter value. The last constraint in Equation (2.c) is the balance sheet identity. It guarantees that the sources ($D + E$) and uses ($B + L$) of funds are equal.

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

[21] The bank is only exposed to credit risk, which is the main thrust for capital regulation. Given the one period timing of the model, operational and interest rate risks are ignored.

[22] The centered and reduced value.

3. The equilibrium equity-to-loan ratio and the required level of CCyB

3.1 Solution to the bank's objective function

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., $(\rho - \bar{s}) \geq r$), maximizing π leads to investing the whole portfolio in loans. However, with the capital constraint, the bank loans are subject to a capital requirement. Therefore, the bank will invest in loans proportionally to its equity E position at date 0. The remaining fund is invested in bonds. The capital requirement and the balance sheet constraints are the main determinants of the bank equilibrium loan level.

Solving the capital and the balance sheet constraints gives us the bank equilibrium equity-to-loan ratio (e^L) choice at date 0. Given that we assume only loans carry risk, the equity-to-loan ratio can be assimilated to a risk-based capital ratio.

Result 1: 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:

$$e^L = \lambda(\alpha + aw_L + r - \rho + \bar{s}), \qquad (3.a)$$

$$\text{with } \lambda = (1 + \frac{A}{E} r)^{-1} \;, \alpha = \sigma F_S^{-1}(1 - p).$$

Proof,

Insert Proof 1 here.

The equity-to-loan ratio obtained from Result 1 exhibits interesting features. Consistent with intuition, it increases with higher expected charge-off rate $\bar{s}$ or higher credit risk (σ), via the term α[23] 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 higher profitability at date 1 will

[23] Note that the distribution function F depends on σ, the volatility of the charge-off rate.

facilitate meeting the capital requirement at date 1. The parameter λ which measures the sensitivity of most parameters featured in our model to the equity-to-loan ratio is positive. Since we are interested in the equity-to-loan ratio's cyclical behavior, we next evaluate its relationship with the business cycle.

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

Let us recall that the main objective of this paper is to estimate the required level of countercyclical capital buffer (CCyB) to cope with the cyclical variations in the bank equity-to-loan ratio. Accordingly, we quantify the cyclical variations in the bank equity-to-loan ratio (Equation (3.a)), by taking the derivative of the equilibrium equity-to-loan ratio around the business cycle.[24] We mainly assume that the parameters or variables in the equilibrium equity-to-loan ratio (Equation (3.a)) vary with the business cycle. We describe their cyclical behavior in the upcoming sub-sections.

3.2.1 Cyclical variations in the risk weights (w_y)

Under the Basel II IRB approach,[25] risk weights on loans (w_L) are functions of the borrower default probability, which is expected to increase in recessions as compared to booms.[26] For instance, Behn et al. (2016) provide evidence of such increase in risk weights and in consequence capital requirement for Spanish banks during the last 2007 subprime crisis. Accordingly, we capture the negative comovement in with the business cycle by expressing the risk weight of loans as a linear function of the business cycle captured by the output gap as follows:

$$w_L(y) = w_{L,0} - \frac{m_w^L}{a}(y - \bar{y}), \qquad (3.b)$$

where, $w_{L,0}$ is considered as the unconditional risk weight and can be viewed as the risk charge in normal times. $\frac{m_w^L}{a}$ is the sensitivity of the risk weights with respect to the business cycle variable captured by the output gap $(y - \bar{y})^{27}$, which is the difference

[24] In the banking empirical literature, the business cycle is commonly proxied by the gap in the gross domestic product (GDP gap).

[25] This is also similar under the standard approach where ratings used in risk weights are also based of firms default probability.

[26] Regarding banks operating under the standardized approach of Basel II, risk weights are based on scores assigned to a particular rating. While cyclicality is contained in "through the cycle" ratings compared to "point-in-time" rating, there is evidence in the literature that the rating cycle is procyclical (see Amato and Furfine, 2004 and Ferri, Liu and Stiglitz, 1999).

[27] $(y - \bar{y})$ 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.

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 the Kashyap and Stein (2004) analysis and in line with Ayuso et al. (2004); Repullo et al. (2010) among others.[28]

3.2.2 The minimum capital ratio (a_y)

As discussed previously, the adoption of the countercyclical capital buffer requirement will directly affect banks minimum capital ratio in accordance with the credit cycle and more specifically, when the level of credit in the economy is judged excessive. In accordance with the existing literature that focus on the business instead of the credit cycle, and given the synchronicity between business and credit cycle, we model the minimum capital ratio required under the CCyB as follows:[29]

$$a_y = a_0 + m_a(y - \bar{y}), \qquad (3.c)$$

where a_0 is the existing Basel II minimum limit of 8% and $m_a(y - \bar{y})$ the countercyclical capital adjustment (CCyB) component. Employing Equation (4), 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 the cyclicality presented in Result 3 below.

[28] 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).

[29] CCyB as implemented under Basel III, can be viewed as a contingent claim, (i.e., an option) on the credit cycle measured by the credit-to-GDP ratio. To apply option pricing theory to model CCyB, one must 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 the macroeconomic conditions. This shifts the bank expected capital minimum requirement level at date 0 but does not affect our overall analysis.

3.2.3 Cyclical variation in credit risk ($\bar{s}_y$) and leverage $(A/E)_y$

The extant literature provides evidence on the negative comovement between credit risk and the business cycle (see Thakor, 2016 and Marcucci and Quagliariello, 2009; among others). We assume the derivative of the credit risk with respect to the business cycle to be negative ($\bar{s}_y$< 0), while the bank deposits and leverage are supposed positively related to the cycle $\left((A/E)_y > 0\right)$. This is sensible. Evidence of positive deposit inflows during market bursts are numerous. For instance, Gatev and Strahan (2006) document inflows of deposits favored by the presence of deposit insurance (see Pennacchi, 2009) during a period of low market liquidity. It is also well known that there are fluctuations in intermediary institutions leverage and real economic activity over business cycles, see among others, Geanakoplos (2010), Adrian and Shin (2014), Halling et al. (2016), Nuno and Thomas (2017).

3. 3 The equity-to-loan ratio over the business cycle and the adequate level of CCyB

Recall that the cyclical variations in the parameters included in the equilibrium equity-to-loan ratio are: the risk weight (w), the expected charge off rate ($\bar{s}$), and leverage ($\frac{A}{E}$). Based on this cyclical variation characterization, the derivative of the equity-to-loan ratio with respect to (y), mimicking the business cycle, delivers the following expression:

$$e_y^L = \lambda_y(\alpha + aw_L + r - \rho + \bar{s}) + \lambda\left(a_y w_L + aw_L(y) + \bar{s}_y\right), \quad (3.d)$$

$$\text{with } \lambda_y = r\lambda^2(A/E)_y$$

Replacing the expression of cyclical variations described in Equations (3.b) and (3.c) in Equation (3.d), we obtain the cyclical variations in the equity-to-loan ratio by means of the following result:

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

$$e_y^L = \lambda_y \frac{e^L}{\lambda} + \lambda\left(-m_w + m_a + \bar{s}_y\right), \ (3.e)$$

$$\text{with } \lambda = \frac{1}{1+\frac{A}{E}r} \text{ and } \lambda_y = r\lambda^2(A/E)_y.$$

Proof,

Insert Proof 2 here.

The first term ($\lambda_y \frac{e^L}{\lambda}$) is proportional to the level of equity-to-loan ratio (e^L) and is positive since both λ and $\lambda_y = r\lambda^2(A/E)_y$ are positive. The second term is likely negative given that two if its terms ($-m_w$ and $\bar{s}_y$) are negative, with only one positive term which is the m_a that comes with the CCyB requirement. Therefore, we can compute the level of m_a or the CCyB size that is required to reduce or annul the cyclical variation in the equity-to-loan ratio.

The CCyB requirement aims at absorbing (or reducing) any cyclicality in bank capital ratios and mitigating the impact of lending curb.[30] 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 determine the level of m_a (m_a^*) or add-on capital required to offset the cyclical variation in the equilibrium equity-to-loan ratio.[31] Using Equation (3. e), we find m_a so that e_y^L = 0. In other words,

$$m_a^* = arg_{m_a}\,(\lambda_y \frac{e^L}{\lambda} + \lambda\big(-m_w + m_a + \bar{s}_y\big) = 0) \quad .$$

<u>Result 3:</u> The adequate level of CCyB (m_a^*) is:

$$m_a^* = \underbrace{-\lambda_y \frac{e^L}{\lambda^2}}_{<0} + m_w - \bar{s}_y \quad (4)$$

The obtained m_a^* has interesting insights for the CCyB design. Its first term, which is negative, is proportional to the bank equity-loan ratio, suggesting that highly capitalized banks will require a lower capital buffer compared to their peers one. The second term (m_w) and the third term ($-\bar{s}_y$) capture the sensitivity of the risk-weight and the credit risk to the business cycle and are both positive. This suggests that banks that exhibit

[30] In fact, 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).

[31] 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 financial stability). We derive in this paper the level of CCyB that is required 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.

highly cyclical risk weights and credit risk should be incentivized to build higher capital ratios in booms. In the next section, we calibrate the obtained m_a^* to bank-level data.

4. Calibration and empirical evidence

Recall that in the previous sections, by focussing on the level of CCyB (m_a^*) that is necessary to contain the equity-to-loan ratio cyclical behavior, we derive several results. Next, using U.S. bank data, first, we calibrate the parameters in the CCyB expression (see Equation (4)), then, we solve the nonlinear equations to obtain the CCyB sizes.

4.1 Calibration

We rely on a U.S. 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 contamination, as banks would then have prepared their regulatory compliance. Data on bank risk-based capital and leverage ratios are available only from 1996.[32] We download U.S. macroeconomic data from the Federal Reserve Economic Data (FRED), a database maintained by the Research division of the Federal Reserve Bank of St. Louis. The Basel I international capital standards were not fully implemented in the U.S. 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 of equally represented (small, medium and large banks).[33] We report descriptive statistics for total assets distribution by terciles in the table below:

[32] 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.
[33] 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.

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

We start by calibrating the parameters and the variables appearing in the expression for CCyB (m_a^*). These variables are the bank leverage ratio ($\frac{A}{E}$) and its risk sensitivity $(A/E)_y$, the loan loss ratio or credit risk sensitivity to the cycle ($\bar{s}_y$), the loan risk weight (w_L) and its sensitivity to the cycle (m_w^L).[34] We set the risk-free bond return (r) at 3.18%.[35] The unconstrained minimum capital ratio a_0 is fixed at 8%, reflecting the Basel II minimum capital requirement.[36] For each variable and parameter, we compute the sample mean and sensitivity with respect to the economic cycle. Using the gross domestic product (GDP) output gap, we then calibrate our model.[37] Formally, we estimate the following regression model for each variable.

$$X_{it} = \beta_0 + \beta_1(y_t - \bar{y}_t) + \varepsilon_{it}, \qquad (5)$$

where $X \in \left\{\frac{A}{E}, w_L, \bar{s}\right\}$ is the model variable or parameter and β_1 the sensitivity of the variable with respect to the output gap measure.

[34] Since an important source of the risk-weighted assets comes from the credit risk (in loan portfolio) we assume that the loan risk weight to be akin to the observed ratio of total risk-weighted assets over total assets.
[35] We proxy the risk-free rate by the average value of the federal funds rate (the interest rate the depository institutions use to trade federal funds (balances held at Federal Reserve Banks) overnight).
[36] 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).
[37] We obtain the output gap by extracting the cyclical component of GDP growth using the Kalman filter approach.

Table 4: Value of the calibrated parameters

This table summarizes the calibrated values of the bank equity-to-loan ratio (e^L), the bank leverage (A/E), the bank total risk-weighted assets density (w), the sensitivity of banks leverage with respect to the cycle variable $(A/E)_y$, the sensitivity of the risk-weighted to the business cycle (m_w) and the sensitivity of the loan loss ratio to the business cycle ($\bar{s}_y$). We use U.S. bank data from the Wharton Research Data Service (WRDS) Bank Regulatory Data and split our sample in three bank size categories (small, medium, and large).

Banks	e^L	A/E	w_L	$(A/E)_y$	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

4.2 Estimation of the required CCyB levels

Recall that the equations for the CCyB required is the following:

$$m_a^* = \underbrace{-\lambda_y \frac{e^L}{\lambda^2}}_{<0} + m_w^L - \bar{s}_y$$

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 ratios. We show the results by bank size: small, medium, large, and for the whole sample.

	m_a^*
Whole sample	0.041
Small	0.031
Medium	0.044
Large	0.052

We report in Table 5, the level of the CCyB (m_a^*) for different bank sizes (small, medium and large). We estimate m_a^* to be 0.06 for the whole sample. The required level increase with bank size. This may be explained by larger cyclical variations in risk weights and credit risk in large banks. Let us recall that under the CCyB requirement, the motion of the minimum capital ratio is the following:

$$a_y = a_0 + m_a(y - \bar{y})$$

a_0 is the minimum 8% advocated by the Basel II.[38] Empirically, the estimated output gap $(y - \bar{y})$ varies between -0.057 and 0.01. The add-on capital $m_a(y - \bar{y})$ will vary accordingly between -0.342% (0.06×-0.057) and 0.06% (0.06×0.01). Therefore, our model implies that under the worst economic scenario corresponding to an output gap of -0.057, the minimum capital ratio should be lowered on average by 0.342% leading to a ratio of 7.65% (8%−0.34%). Conversely, during booms, our model predicts that the minimum capital ratio should on average increase by 0.06% reaching 8.06%. Recall that add-on capital under Basel III could increase up to 2.5% which is larger than our finding and this add-on capital is not expected to be negative as our simulation suggests in difficult economic times.

5. Potential impact of the LCR requirement on CCyB

Under Basel II, and prior to the GFC, they were no explicit quantitative liquidity requirements on banks (e.g., Yankov, 2020). However, following the liquidity crisis that unfolded during the 2007 GFC, the importance of regulatory monitoring of banks liquidity was starkly underscored. Two new liquidity rules were introduced and will be jointly regulated along side the CCyB buffer. These are the liquidity coverage ratio (LCR) and the net stable funding ratio (NSFR). The liquidity coverage ratio (LCR) aims at improving banks' short-term resilience to liquidity shocks and the net stable funding ratio (NSFR) should reinforce banks' structural liquidity resilience in the medium and long-term. Since our model examines the bank's reaction in the short term, we focus on the LCR requirement, a token of this short-term perspective. This leads us to study the LCR impact on the required level of CCyB (m_a^*). In this paper, we focus only on LCR and leave out NSFR since incorporating both LCR and NSFR will bring us too far.

5.1 The liquidity coverage ratio (LCR) requirement

The LCR is introduced under the Basel III framework in 2010. Its adoption in the U.S has been finalized in 2014. The LCR aims 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). It applies to large and internationally active U.S. bank holding companies with US$ 250 billion or more in assets or US$ 10 billion

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

or more in on-balance sheet foreign exposure due to their complexity, funding profiles, and potential risk to the financial system (Du, 2017). We provide below a brief description of the LCR outlined by BIS (2018).[39] The liquidity ratio (LCR) is computed as the ratio of High-Quality Liquid Assets (HQLA) to net outflows (30 days).[40]

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

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. More importantly, and according to the BCBS guidelines, weights are inversely related to the credit risk of the eligible assets.[41] The minimum requirement of 100% for the LCR was expected to be effective on January 1, 2019.[42] Regarding the denominator of the ratio, namely the total net cash outflows over the next 30 days (hereafter net outflows) is obtained as follows:

$$\begin{aligned} Net\ outflows = {} & Total\ expected\ cash\ outflows \\ & - min\ (Total\ expected\ cash\ inflow, 75\%\ of\ total\ expected\ cash\ outflows) \end{aligned}$$

Like the HQLA, the total expected cash outflows are calculated by multiplying the outstanding balances of various categories or types of liabilities and off-balance sheet commitments (d_i) by the rates at which they are expected to run-off or haircut δ_i.[43]

[39] See BIS (2018) for a complete overview.

[40] Loans are not eligible for HQLA.

[41] 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.

[42] Specific timing of the LCR implementation varies with each country objective. 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.

[43] For example, liabilities such as deposits are divided in two groups: the stable and less stable deposits with respective haircuts δ_i of 3% and 10%. Stable deposits concern mostly insured deposits or deposits eligible for deposit insurance.

5.2 The adequate level of CCyB under the LCR requirement

To analyze the LCR implications for the adequate level of CCyB, we add the LCR constraint into the bank optimization problem and we estimate banks' equity-to-loan ratios. To do this, we introduce a liquidity requirement that mimics the Basel III short-term LCR liquidity rule as an additional constraint in our representative bank's asset allocation. 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. In order to indemnify insured depositors of closed banks (see Calomiris et al., 2016), regulators require banks to hold a minimum level of liquid assets (which is proportional to the bank deposits and expected profitability) to facilitate their asset liquidation at date 1.

Now, let us motivate the specification of our LCR constraint. We underline, in the previous section, that under the LCR regulation, the liquidity weights assigned to assets are negatively proportional to the corresponding risk weights. Without loss of generality, and given that our bonds are assumed first, risk-free, they are fully eligible for HQLA (High Quality Liquid Asset) equal to B.[44] For the denominator of the ratio, i.e., the net outflows, it is obtained as the expected outflows (δD) net of inflows which is the retained profit ($(\rho - \bar{s})L + rB$) at date 1. Then, the LCR constraint takes the following form:

$$LCR = \frac{B}{\delta D - [(\rho - \bar{s})L + rB]} \geq 1$$

or, equivalently

$$B \geq \delta D - (\rho - \bar{s})L - rB \qquad (6.a)$$

Given that loans are preferred to bonds in risk-return term, we assume that the constraint binds and that banks hold the minimum possible liquidity to meet the LCR requirement. We obtain the equity-to-loan ratio expressed by the result below:

$$e^L = \kappa\big(\alpha + aw_L - r\xi\delta + (r\xi - 1)(\rho - \bar{s})\big) \quad (6.b)$$

[44] We consider later risky bonds, where only a proportion of the bonds is eligible for HQLA purposes.

with $\kappa = \frac{1}{(1-r\xi\delta)}$ and $\xi = \frac{1}{(1-\delta+r)}$.

The equilibrium equity-to-loan ratio e^L depends on the deposit haircut δ (a key parameter for the LCR constraint equation) imposed 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. Contrary to the No-LCR case, it is worth noting that the bank leverage ($\frac{A}{E}$) no longer affects the optimal equity-to-loan ratio.

<u>Result 4:</u> Under the LCR requirement, the required equilibrium CCyB to annul the cyclical variation in e_y^L is:

$$m_a^* = \underbrace{r\xi\bar{s}_y}_{<0} + \boldsymbol{m_w} - \boldsymbol{\bar{s}_y}, \qquad (7)$$

$$\text{with } \xi = \frac{1}{(1-\delta+r)}$$

See Proof 1.2

5.3. The effect of LCR requirement on the adequate level of CCyB

To recap, in the above, we have computed the required adequate level of CCyB as follows:

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

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

$$\text{With } \lambda = \frac{1}{1+\frac{A}{E}r},\ \lambda_y = r\lambda^2(A/E)_y \text{ and } \xi = \frac{1}{(1-\delta+r)}$$

Let us look at m_a^*, the optimal CCyB for both regulatory set-ups (with and without the liquidity requirement). Both expressions contain the term $\boldsymbol{m_w} - \boldsymbol{\bar{s}_y}$ which suggests that the CCyB required level should help to contain the main two sources of cyclical variations in the equity-to-loan ratio, namely, the sensitivity of risk-weighted with respect 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 ($-\lambda_y \frac{e^L}{\lambda^2}$ $and\ r\xi\bar{s}_y$) that are both negative. Therefore, our finding suggests that the difference in the CCyB when liquidity is regulated, compared to the no liquidity case, will depend on the deposits haircut (δ) that is specific to the LCR requirement, namely, the leverage ($\frac{A}{E}$) and the credit risk levels ($\bar{s}_y$).

We compute the required level of CCyB for various level of deposit haircuts ranging from 3% to 40%, depending on the bank deposits stability as suggested by the Basel III requirement (BCBS, 2019).[45] Table 6 summarizes our main findings.

Table 6: The CCyB under the liquidity coverage ratio (LCR) requirement

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) previously reported in Table 5 and the cases with the liquidity requirements (other columns) with different values of the deposit haircut (δ), viewed as the liquidity weight metric attributed to the deposits under Basel III. Results are reported by bank size: small, medium, large, and for the whole sample.

m_a^*	No LCR	With LCR requirement			
Risk-free bonds, $w_B = 0$		δ = 0.03	δ = 0.10	δ = 0.2	δ = 0.4
Whole sample	0.041	0.076	0.076	0.076	0.075
Small	0.031	0.041	0.040	0.040	0.040
Medium	0.044	0.079	0.079	0.079	0.078
Large	0.053	0.111	0.110	0.109	0.109

In general, the required level of CCyB is higher for the medium and large banks compared to the smaller ones. This is explained by their high leverage and the large cyclical variations in their credit risk. Regarding the joint regulation of CCyB and the LCR, there is evidence that the CCyB level is higher when liquidity is regulated (Table 6, Column 2-4) compared to the case with no LCR requirement (Table 6, Column 1). Intuitively, the LCR, by requiring banks to hold a minimum level of bonds, reduces their expected profit[46] and consequently, their available profit to meet the capital requirement at the end of period 1.

Table 6 also suggests that the level of CCyB is stable with several levels of deposit haircuts (δ). This finding suggests that the increasing level of CCyB under the LCR is mostly driven by the imposition of a minimum level of bond holdings, rather than the

[45] One can interpret this as a haircut on the bank's deposits. Less stable and short-term deposits necessitates higher haircuts since they are more likely to be withdrawn.
[46] The LCR might induce banks to hold a level of bonds that is higher than their allocation in absence of the LCR.

required volume of bonds that depends on deposit haircuts size. In addition, given the small differences in the CCyB sizes between the cases with LCR regulation and the cases without it, we can conclude that a large proportion of the required CCyB is attributable to the sum of the credit risk and the cyclical variations ($\boldsymbol{m_w} - \bar{\boldsymbol{s}}_{\boldsymbol{y}}$) in risk weights.

Insert Figure 1 here

In our previous analysis, we consider a risk-free rate of 3.18% that reflects the average value during the studied period. We further assess the risk-free rate impact by varying it from 1% to 5%. Our finding reported in Figure 1 shows that the required levels of CCyB are higher with lower interest rates. This suggests that the bond effectiveness in attenuating bank profits cyclicality is lessened in a low interest rate environment.

6. Analysis with risky bonds

6.1 The CCyB with risky bonds without the liquidity (LCR) requirement

In the preceding analysis, we first assumed that bonds are risk-free ($w_B = 0$). However, banks can invest in risky bonds affecting their total risk and consequently their capital requirements. Under the risky bonds assumption, the capital constraint (2.b) becomes:

$$prob\left(\frac{E+\pi}{w_L L + w_B B} \leq a\right) \leq p, \qquad (8.a)$$

where w_L and w_B[47] are the risk-weights for banks loans (L) and risky bonds (B) respectively.[48] $w_L L + w_B B$ is the total asset risk in terms of the risk-weighted assets, a bank equity-capital cushioning metric.

Given that risk-weights associated with bonds fluctuate over the business cycle, bonds will carry risk weights that must be taken into account in the capital constraint.

The bank problem is then stated as follows:

[47] Regarding the relationship with the business cycle, we assume that bonds risk weights exhibit similar patterns as loans risk weights as stated in Equation (5).

[48] In addition, regulators impose a countercyclical capital buffer and the liquidity requirements.

$$Max_{L,B}\ \pi = (\rho - s)L + \gamma B$$
$$s.t$$
$$prob\left(\frac{E+\pi}{w_L L + \boldsymbol{w_B B}} \leq a\right) \leq p,$$
$$B + L = D + E$$

6.1.1 The equilibrium equity-to-loan ratio

By solving the preceding bank problem, we obtain the following result:

<u>Result 5:</u> The equilibrium equity-to-loan ratio e^L under the risky bond assumption is:

$$e^L = \lambda(\alpha + a(w_L - \boldsymbol{w_B}) + \boldsymbol{\gamma} - \rho + \bar{s}), \qquad (8.b)$$

with $\lambda = \frac{1}{1 - \frac{A}{E}(\boldsymbol{a w_B} - \boldsymbol{\gamma})}$

See Proof 2.1

The equity-to-loan ratio obtained from Result 5 exhibits similar features with the one obtained under the assumption of a risk-free rate. The risk weight linked to the risky bonds is positively associated with the equilibrium equity-to-loan ratio by way of the denominator of λ. This risk weight is negatively associated to λ throughout the remaining terms. The net effect will depend on other parameters and will be gauged later by means of our calibration exercise. The term λ measures the sensitivity of most parameters featured in our model with respect to the equity-to-loan ratio. Therefore, λ should be positive, and the condition to obtain this is $(a w_B B - \gamma) \leq \frac{E}{A}$. Since we are interested in the cyclical behavior of the equity-to-loan ratio, we evaluate next, its relationship with the business cycle.

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

As for loans, we assume that the bond portfolio risk is cyclical according to the specification below:

$$w_B(y) = w_{B,0} - \frac{m_w^B}{a}(y - \bar{y}), \quad (8.c)$$

where $X \in \{B, L\}$, $w_{B,0}$ is the unconditional risk weight of bonds and can be viewed as the risk charge in normal times. $\frac{m_w^B}{a}$ is the sensitivity of the risk weights with respect to the business cycle.

Result 6: The sensitivity of the equilibrium equity-to-loan ratio e^L is:

$$e_y^L = \lambda_y \frac{e^L}{\lambda} + \lambda\big(m_a(w_L - w_B) - m_w^L + m_w^B + \bar{s}_y\big), \qquad (8.d)$$

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

See Proof 2.2

There is evidence that the risk weight w_B associated with risky bonds affects both the level and the sensitivity of the equilibrium equity-to-loan ratio with respect to other parameters such as credit risk and expected return. Based on Equation (8.d), we compute the level of m_a (m_a^*) or add-on capital that is required to offset the cyclical variation in the equilibrium equity-to-loan ratio. In other words,

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

Unlike the cases with riskless bonds (See Equation 7), m_a^*, the solution for the previous equation cannot be obtained analytically, therefore, it will be found by way of an optimization algorithm.

6.2 The CCyB with risky bonds under the liquidity (LCR) requirement

Allowing for risky bond has also an implication for the CCyB under the liquidity requirement (LCR). Unlike the risk-free case, bonds are no longer fully eligible for liquidity purpose. Rather, their eligible value is proportional to their liquidity weight that is inversely proportional to their credit risk weight. Formally, the bank total HQLA is $(1 - w_B)B$, with w_B the bond risk weight. Therefore, we assume the binding liquidity constraint stated as follows:

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

Solving the equity-to-loan ratio problem with the new LCR constraint delivers the following result:

<u>Result 7:</u> The equilibrium equity-to-loan ratio under the LCR requirement with risky bonds takes the following form:

$$e^L = \phi\big(\alpha + aw_L + \xi\varphi\,(aw_B - \gamma) - (\rho - \bar{s})\big), \quad (10.b)$$

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

Proof 2.3

We obtain the cyclical behavior of the capital ratio under the LCR requirement (with risky bonds), in the same fashion as before, by computing the derivative of the equity-to-loan ratio with respect to the business cycle. We summarize the obtained cyclical relation as follows:

<u>Result 8:</u> In presence of risky bonds and the liquidity requirement, the sensitivity of the equilibrium equity-to-loan ratio e^L with respect to the business cycle is the following:

$$e_y^L = \phi_y \frac{e^L}{\phi} + \phi\big(\boldsymbol{m_a w_L} - m_w^L + (aw_B - \gamma)\big(\xi_y\varphi + \xi\bar{s}_y\big) + (\boldsymbol{m_a w_B} - m_w^B)\xi\varphi + \bar{s}_y\big), (10.c)$$

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 $\xi_y = \frac{-m_w}{a(1-w+\gamma-\delta)^2}$.

Similarly, we obtain the required CCyB level to offset the cyclical variation in the equity-to-loan ratio by solving the following non-linear equation:

$$m_a^* = arg_{m_a}\left(\phi_y \frac{e^L}{\phi} + \phi\big(\boldsymbol{m_a w_L} - m_w^L + (aw_B - \gamma)\big(\xi_y\varphi + \xi\bar{s}_y\big) + (\boldsymbol{m_a w_B} - m_w^B)\xi\varphi + \bar{s}_y\big) = 0\right)(10.d)$$

In the next section, to study the effects of the LCR requirement, we perform an empirical calibration of our model. Note that unlike in the risk-free case, the CCyB depends on loan profitability $(\rho - \bar{s})$, the risky bonds return γ and the run-off on deposits δ.

7.3 The CCyB with risky bonds: The effect of the LCR requirement

Allowing jointly for the presence of risky bonds and the liquidity requirement brings a trade-off newly uncovered in the model. In fact, the higher the bond risk and the lower is its contribution to the LCR requirement. To study explicitly the "risk-liquidity" interplay, we first compute the required CCyB with risky bonds in the absence of the liquidity requirement (i.e., in absence of this risk-liquidity trade-off) and then, we compare the outcomes with the case with the liquidity requirement.

Estimating the behavior of the CCyB under the risky bonds case, requires that we quantify the returns on risky bonds and loans separately. We also need data on the differing risk weights of loans and risky bonds. Since these informations are not available in the database we built for our calibration exercise (see Sub-section 4.1), we rely on the FDIC's bank quarterly profile to approximate these values.[49]

Insert Figure 2 here

We estimate the loan portfolio return $(\rho - \bar{s})$ by dividing the total loan income (net of charge-offs) by the total net loans and leases. Regarding the risky bond return γ, we obtain it, as the ratio of income on securities (including trading accounts) to total securities.[50] We obtain an average yearly return of 5.76% versus 6.08% for bonds and loans respectively. With the exception of the financial crisis period (2007Q3 to 2010Q3), returns on loans are higher than those on securities as depicted in Figure 2. On average, over the period of study (1996-2011), the loans risk premium over the bond return averages 0.32% (6.08% - 5.76%) and might be explained by the interactions and mixes of risk factors such as liquidity, portfolio allocation, diversification across asset classes, securitization, to name a few in the bond and loan tradeable and uninvestable markets and exchanges.

Concerning the computation of risk weights on loans versus those on bonds ($\boldsymbol{w_L}$ versus $\boldsymbol{w_B}$), we lack granularity on the distinct contributions and attributions of loans versus securities to the total risk-weighted assets.[51] Hence, we formulate that the

[49] https://www.fdic.gov/analysis/quarterly-banking-profile/

[50] Securities might include stocks, governments bonds. However, given the structure of our model, risky bonds designate any investment, except loans into which banks invest their funds. In addition, there is no granular data on risky bonds income separately disentangled from others securities.

[51] Data on risk-weights is only available on aggregate basis. However, credit risk is the most important component of total risk-weights.

bonds' risk weight is proportional to the loans risk weight, with proportions based on the ratio of the returns on the two asset classes. Given the original loan risk weight of 0.649 for the whole sample and the ratio of returns is 0.94 ($\frac{5.76\%}{6.08\%} = 0.94$), we obtain an equivalent bonds' risk weight of $\boldsymbol{w_B}$ = 0.615 (0.649×0.94).

Under this set-up, we summarize our findings in Table 7 below.

Table 7: The CCyB with risky bonds and liquidity (LCR) requirement

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 under the risky bonds holding assumption. The scenarios are the "no liquidity" or "no-LCR" case (first column) and the cases with the liquidity requirement (other columns) with different values of the deposit haircut (δ), viewed as the liquidity weight metric attributed to the deposits under Basel III. Results are reported by bank size: small, medium, large, and for the whole sample.

$\boldsymbol{m_a^*}$	**No LCR**	**With LCR requirement**			
(Risky bonds, $w_B \neq 0$)		δ = 0.03	δ = 0.10	δ = 0.2	δ = 0.3
Whole sample	0.073	0.130	0.107	0.084	0.052
Small	0.032	0.072	0.059	0.046	0.029
Medium	0.079	0.134	0.111	0.089	0.056
Large	0.104	0.183	0.148	0.113	0.066

A comparison between Table 6 (with risk-free bonds) and Table 7 suggests that, by and large, the required level of CCyB increases when bonds are risky compared to the risk-free case. For large banks, the required CCyB under the risky bond's assumption amounts to $m_a^* = 0.104$ of the output gap (see Table 7 Column 1) in the risky bond case compared to m_a^* =0.053 of the output gap in the risk-free bonds case (see Table 6, Column 1). A possible explanation is that additional cyclical variations from the risky bonds weights amplify the cyclical variations in the bank capital ratio, which appears in the denominator aggregating into the total risk-weighted assets.

As in the risk-free bond case (Table 6), the required level of CCyB increases with the introduction of the LCR requirement. There is, however, evidence that as the level of required liquidity increases (higher haircut, e.g., δ = 0.3), the required level of CCyB is reduced considerably. When the liquidity requirement is introduced, the level of CCyB is higher for lower deposit run-off rate. In fact, the liquidity requirement, under the assumption of substitutability between bonds and loans, will force banks to hold risky bonds to meet the LCR requirement. Our analysis suggests that for very stable deposits (lower run-off rate δ), there is a “risk-liquidity” trade-off imbedded in the LCR requirement. The risky bonds’ liquidity weights are inversely proportional to the credit risk and therefore are likely to decrease in recessions, putting pressure on banks to invest more in risky assets in order to meet the LCR requirement. However, this “risk-liquidity” trade-off becomes beneficial for high level of deposit run-off rate suggesting that imposing the LCR requirement for banks with less stable deposits will help them to reduce the cyclical variations of their capital ratios.

Insert Figure 3 here

Insert Figure 4 here

We focus our previous scenario analyses based on calibrated values on the studied period. To improve our simulation, we consider other possible values of the loan portfolio returns ranging from 5% to 10% (annually) based on historical data covering the 1984-2022 period (see Figure 2). Based on the loan returns data, we derive an equivalent bond return values by assuming a proportionality coefficient of 0.94 ($\frac{5.76\%}{6.08\%} = 0.94$).[52] Finally, we also consider cases in which a higher level of risk premia is considered for loans versus securities, with the annual premium spanning from -2% to 2%[53](see Figure 3). We plot the case without the liquidity requirement in Figure 4. It suggests that the higher the return on a loan portfolio, the higher is the CCyB. The LCR constraint entails that the level of bond holdings is reduced when the expected profit is high. Then, in a period of more profitable investment in bonds, the requirement from bond holdings decreases and banks can invest more in loans causing elevated cyclical variations. Recall that an important portion of the cyclical variation embedded in the CCyB comes from the credit risk from the loan portfolio ($\bar{s}$).

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

[52] This is similar to the hypothesis that the expected return on loan is proportional to expected return on bond securities.

banks to increase their capital buffer through the cycle, with a double goal of reducing excessive credit growth and building the necessary buffer to cope well in future downturns.

However, most of the existing solutions addressing this issue of cyclicality mostly focus on the regulatory minimum capital requirement instead of bank actual capital ratios. Since banks mostly adjust towards their internal capital ratio, we explicitly model the cyclical variations in bank capital ratios and derive the required drivers of the optimal countercyclical CCyB that mitigate cyclicality in the bank capital ratio. 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 bank capital ratios. We uncover and explain the amplification effect 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.

We offer the following takeaways for policy-makers: 1- the account for the potential effect of LCR when designing CCyB; 2- the CCyB effect, that is needed to mitigate the cyclical variation in the bank equity-to-loan ratios, varies significantly with bank size precluding one-size-fits-all approach in CCyB design; 3- relaxing the LCR requirement during downturns or setting the countercyclical LCR requirement might be desirable to contain LCR cyclical variations and the LCR potential effects on the cyclical variations in bank equity-to-loan ratios, and 4- the impact of LCR on the required CCyB level is attributable to the risk-liquidity trade-off that comes with the LCR requirement.

Our study is most fitting in light of the subsiding 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 usable capital to support lending and the banking industry to preserve and boost capital to weather robustly the 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 the dynamic framework.[54] By interacting and stabilizing macroeconomic variables CCyB affect business cycle dynamics, therefore, it becomes desirable to account for these in CCyB design. Last but not least, it would be interesting to model the countercyclical capital buffer as a put option on the aggregate macroeconomic variables.

[54] 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. Central banks and regulatory bodies will provide guidance on the specific application of the HQLA as witnessed during the 2020 COVID-19 outbreak.

Appendix. Proofs of results

Proof 1

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

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

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

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

Scaling by loans (L), we obtain:

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

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

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

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

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

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

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

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

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. Assuming that the capital constraint binds given that capital is costly, we obtain:

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

with $\lambda = \frac{1}{1+\frac{A}{E}r}$ 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:

Proof 1.1

- *CCyB without the LCR requirement*

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

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

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

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

Proof 1.2

- *CCyB with the LCR requirement*

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

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

Assuming that the liquidity constraint binds, which is plausible given that loans are better than bonds in risk-return terms, we get the following expression:

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

By scaling B by the total loans L, we get:

$$b^L = \frac{\left(\delta - (\rho - \bar{s})\right) - \delta e^L}{(1 - \delta + r)}$$

$$b^L = \xi(\delta - (\rho - \bar{s}) - \delta e^L)$$

With $\xi = \frac{1}{(1-\delta+r)}$

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

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

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

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

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

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

Assuming the capital constraint to be binding, we obtain:

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

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

Taking the cyclical behavior delivers:

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

and $\kappa_y = 0$. Therefore, e_y^L reduces to: $e_y^L = \kappa\big(-m_w + m_a + (1 - r\xi)\bar{s}_y\big)$.

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

$$\boldsymbol{m_a^*} = r\xi\bar{s}_y + \boldsymbol{m_w} - \boldsymbol{\bar{s}_y}$$

Proof 2 : CCyB with risky bonds

Proof 2.1: The equilibrium equity-to-loan ratio with risky bonds without the LCR

Our objective is to determine the capital ratio level that solves 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:

$$1 - prob(s \leq e^L + \rho + \gamma b^L - a w_L - a w_B b^L) \leq \ p.$$

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

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

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

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 bond-to-loan ratio b^L can be expressed in terms of the 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 out e^L, we get the equilibrium level of capital ratio e^L that depends on exogenous parameters. Assuming that the capital constraint binds given that capital is costly, we obtain:

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

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

Proof 2.2: Cyclical variations in the equilibrium equity-to-loan ratio without the LCR

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:

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

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

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

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

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 2.3: Cyclical variations in the equilibrium equity-to-loan ratio with LCR

The equilibrium equity-to-loan ratio can be rewritten as follow:

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

The main difference with the previous derivation is that banks should account for the LCR in the decision of how much they should invest in bonds. We derive the required level of bonds from the LCR constraint equation as follows:

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

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

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

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

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

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

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

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

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

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

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

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

Figure 1: CCyB (m_a) with risky bonds in absence of the LCR

This figure plots the level of countercyclical capital buffer CCyB that is required for different bank size under several scenarios of the risk-free rate ranging from 1% to 5% in the absence of the liquidity coverage ratio (LCR) requirement. The calibration is based on the U.S bank holding companies accounting data covering the 1996-2011 period.

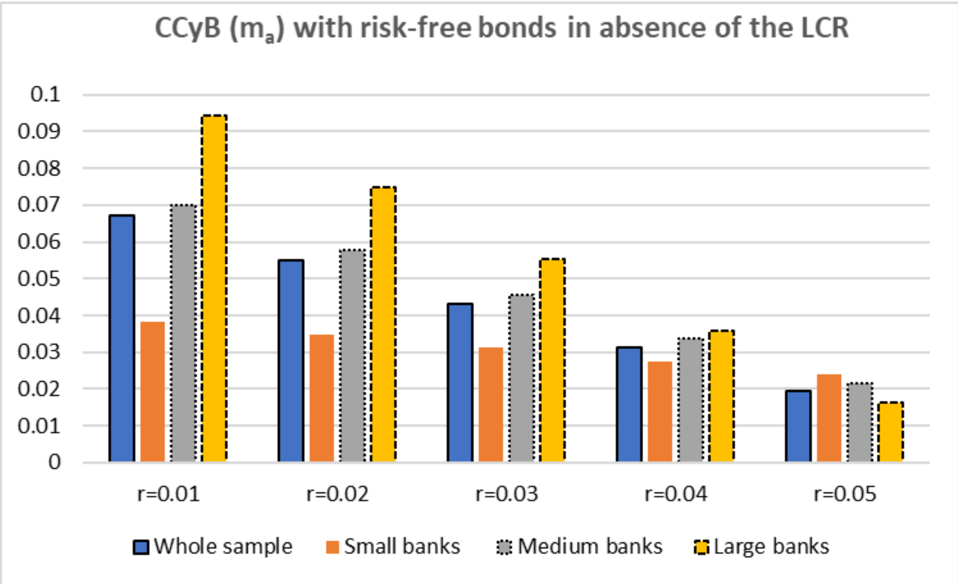


Figure 2: Loan versus securities returns (annualized)

This figure plots historical returns on loan and securities for the US banks for the 1984- 2022 period. Data are extracted from the bank quarterly profiles published by the FDIC.

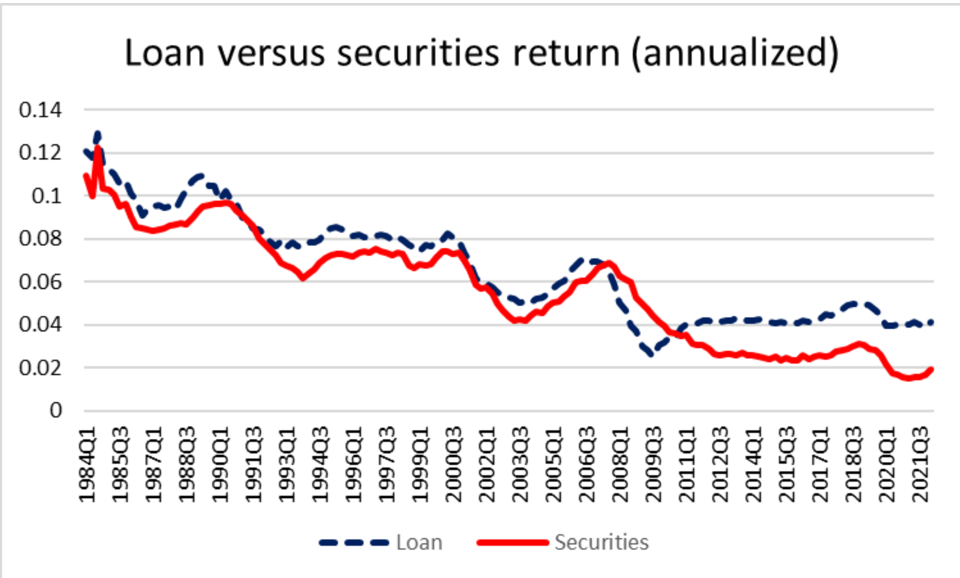


Figure 3: Loan versus securities spread (annualized)

This figure plots the annualized historical spread between loans and securities for the US banks for the 1984- 2022 period. Data are extracted from the bank quarterly profiles published by the FDIC.

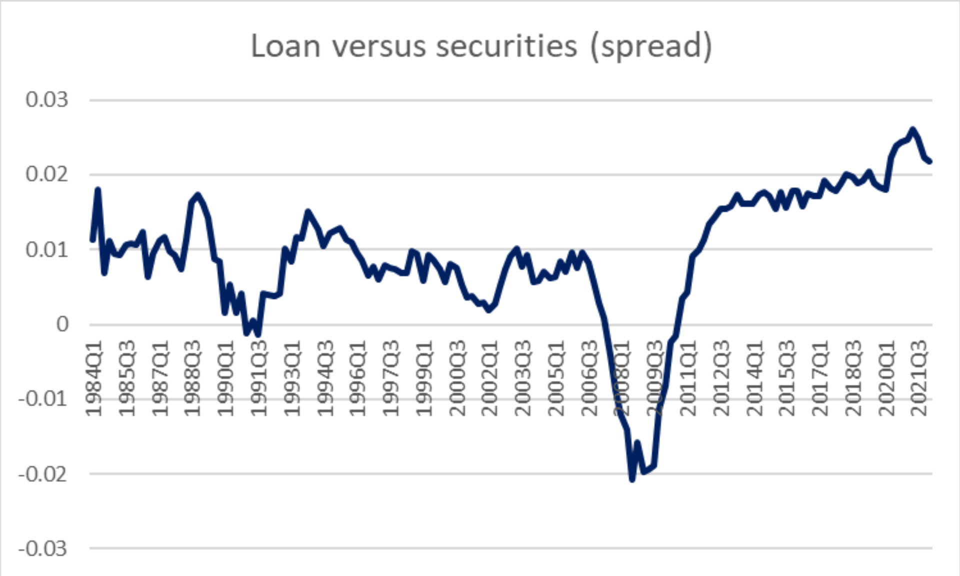
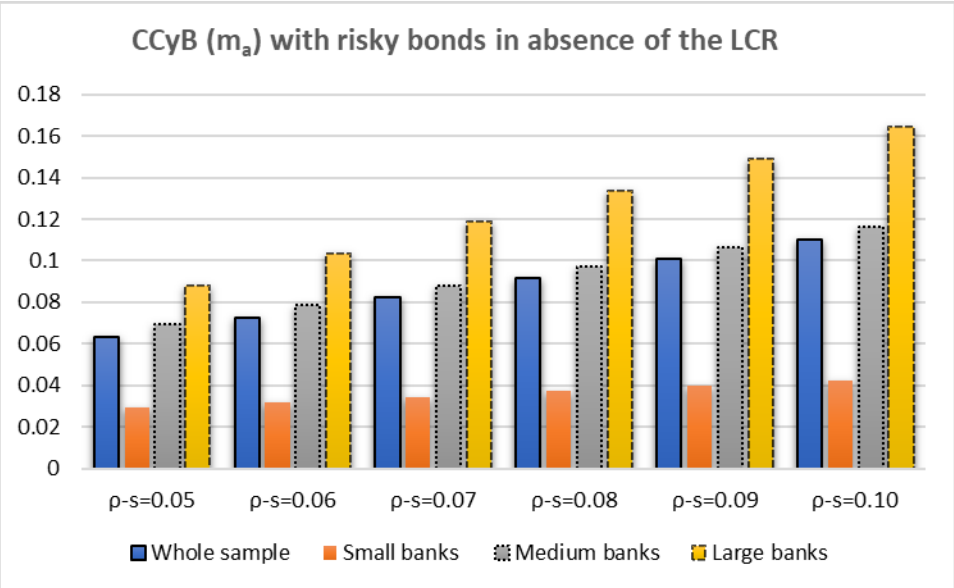


Figure 4: Loan versus securities spread (annualized)

This figure plots the level of countercyclical capital buffer CCyB that is required for different bank size under several scenarios of risky bond holdings in the absence of the liquidity coverage ratio (LCR) requirement. Returns on loan portfolios range from 5% to 10%. The calibration is based on the U.S bank holding companies accounting data covering the 1996-2011 period.



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