Basel III joint regulatory constraints: interactions and implications for the financing of the economy-Preliminary Draft*

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Abstract

This paper examines the impact of multiple regulatory constraints on the financing of the economy in the context of the implementation of the Basel III regulation on capital and liquidity. We propose a simple theoretical model of bank lending decision to analyse the interactions between these various regulatory requirements and the conditions under which some contraints may bind while others may not. Building on the predictions of this theoretical model, we estimate the impact of these different regulatory requirements on lending growth, on a panel of 120 French banks since 2014. Our results indicate that three pairwise interactions, most of them involving the risk-based Tier 1 capital management buffer, have a significant effect on lending growth. More specifically, our results highlight a significant and partial level of substitutability between the risk-based Tier 1 capital management buffer and the LCR over the entire period. We also emphasize the specificity of the lending behaviour of banks with lower regulatory ratios and the changes observed in periods of financial stress. Our results show that the risk-based Tier 1 capital management buffer interacts more with the other ratios, in particular with the leverage ratio and the LCR, during such periods and for weaker banks, with the positive individual effect of regulatory ratios on lending growth partly reduced by the effect of their interactions.

Keywords: Bank Capital Regulation, Bank Liquidity Regulation, Basel III, stress tests

JEL classification: G28, G21

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1 Introduction

The Global Financial Crisis of 2007-09 (GFC) uncovered a number of shortcomings in existing banking regulation. In response, the Basel Committee on Banking Supervision (BCBS) redesigned and completed existing prudential rules. Specifically, the new Basel III framework introduced minimum liquidity requirements in addition to the existing capital requirements, which were not only also tightened but also complemented by a leverage ratio, and lately by an output floor. The new liquidity standards include a Liquidity Coverage Ratio (LCR), which aims to ensure that banks hold enough liquid assets to withstand creditor runs during periods of financial stress, and a Net Stable Funding Ratio (NSFR), which prevents banks from using short-term funds to finance long-term or less liquid loans.

The resulting package is thus characterised by its reliance on multiple regulatory requirements to deliver both the safety and soundness of individual banks as well as the stability of the financial system. Assessing the outcome of these reforms is crucial to guarantee that they reach their intended goals without being economically and socially too costly. Regulators indeed need to make sure that capital and liquidity standards are adequately calibrated. Furthermore, as the acceptance of stricter regulatory rules tends to decline as the effects of the crisis fade, their effectiveness and accuracy need to be challenged on a regular basis.

Assessing the new rules is nevertheless difficult given the lack of historical depth, due to implementation delays and the phasing-in of the different standards, combined with a high degree of uncertainty regarding the measure of liquidity and its optimal level. This assessment is even more challenging when considering the interactions between liquidity and capital standards. Understanding the interactions between these regulatory measures is needed as their compounded effect might differ from the individual effects of each rule taken separately. History also tells us that banks are adept at regulatory arbitrage and innovating their way around regulatory constraints. One has also to check that the incentives are appropriately set so as to avoid that the new rules do not lead to unexpected behavioural responses by banks. For example, some studies show that banks might already have bypassed the new liquidity rules by increasing their long-term borrowing (to "artificially" improve their NSFR) from non-regulated entities that borrow short at a lower cost (Sundaresan and Xiao (2022)).

The current paper focuses on the joint impact and the interactions of capital and liquidity requirements on credit distribution. The remainder of this paper is organised as follows. Section 2 reviews the literature on the interactions between capital and liquidity ratios and their effects. Section 3 presents the theoretical model while Section 4 is devoted to the empirical analysis. Section 5 concludes.

2 Literature review

This paper focuses on the joint impact and the interactions of capital and liquidity requirements on lending growth. Conceptually, three types of potential interactions can be envisaged: i) complementarity; ii) substitutability; and iii) independence. The literature has started providing some elements on what complementarity and substitutability between two requirements mean as well as their implications in terms of actual effectiveness or redundancy of combining the two rules (see among others DeYoung et al. (2018) and Vo (2021)). Indeed, risk-based capital ratios compare equity to asset mix whereas liquidity ratios compare funding mix to asset mix and hence both constraints are linked. It is therefore important to go beyond the mechanical link between the two and draw actual changes in bank behaviour.

On the one hand, the Basel III framework as a whole would be validated if one finds that liquidity and capital standards are complementary, addressing different types of externalities or sources of risk while reinforcing each other. For example, if holding more capital is costly, banks can have incentives to take on higher liquidity risk and reduce lower-yielding liquid assets holdings. In such a case, adding liquidity requirements to capital requirements could be necessary to avoid banks from taking too much liquidity risk. Note that complementarity could also work the other way around. For example, a liquidity constraint that would reduce bank profitability could encourage banks to take higher risk to limit the negative impact on profits. In that case, capital requirements would be complementary to liquidity requirements: adding a capital rule to a liquidity rule would be necessary to limit risk taking. Moreover, complementarity could also only work one way round. Adding rule A to rule B could be necessary but adding rule B to rule A might not be.

On the other hand, the opponents of adding liquidity rules to capital rules in the Basel framework consider that liquidity regulation and capital regulation are substitutes. Substitutability between standards is more of an issue for the overall assessment as this would mean that costs are additive to banks, but that benefits in terms of stability are not. Some argue that the most important dimension is capital and not liquidity (Admati and Hellwig (2013)). If capital regulation is risk-weighted, banks will have incentives to hold low-risk assets which are generally more liquid. Hence, if they are required to hold more capital, banks will comply with the capital rule by also improving their liquidity. If they do not hold enough capital banks could also have incentives to improve their liquidity. Indeed, if they hold enough capital, banks can easily and cheaply access liquidity from the market or from the central bank and they will be less subject to runs. But, if they do not hold enough capital, banks will have incentives to hold more precautionary liquidity because the cost of raising new funds is higher (because of their lower solvency) or to make depositors more confident. Moreover, Bolton et al. (2019) conclude that the Liquidity Coverage Ratio and the Net Stable Funding Ratio, the two liquidity ratios introduced by Basel III, are redundant insofar as the fulfillment of one of the two ratios necessarily entails the fulfillment of the other one, when looking at the balance sheet of a bank.

It could also be argued that when one constraint tightens, the other one could be unaffected, in which case capital and liquidity would be considered as independent. In that case, it is not clear whether the two constraints need to be implemented at the same time. The two rules might have the same objective i.e. limit risk-taking or follow different objectives. Hence, it could be necessary and effective to implement them jointly. However, the rationale behind introducing either of them is not driven by the need to offset the undesired effect that one of the two rules could have on bank behaviour necessitating the introduction of the other rule. On the whole, complementarity and substitutability are a matter of degree and can either operate partially of fully. Therefore, the extent to which a rule might need to be added to another rule will depend on how weakly or strongly they interact. However, because there is no clear understanding of how bank behaviour changes in the presence of a single constraint (capital rule), adding a second constraint (liquidity rule) makes it extremely complex to predict how banks will behave.

The interactions between capital and liquidity rules can be analysed from three perspectives: (i) the possible outcomes of such interactions in terms of banks' default risk and the implications for financial stability, (ii) the impact of such interactions on bank lending behaviour and the potential net benefits of the joint regulation of capital and liquidity, and (iii) areas for future research and recommendations. Our paper will focus on the specific channel of bank lending behaviour by assessing the impact of multiple regulatory constraints on credit distribution. As mentioned previously, when assessing banks' behaviour in reaction to balance sheet restrictions, it is crucial to understand that restrictions placed on one portion of the balance sheet may lead to compensating changes elsewhere. By reducing banks' balance sheet flexibility, tougher capital and liquidity requirements might encourage banks to grant fewer loans, thus offsetting some of the desired benefits in terms of global social welfare. Alternatively, banks could respond by making riskier loans (optimizing the risk buckets for RWA calculations) or by increasing lending rates (for a given risk).

De Nicolo et al. (2014), Behn et al. (2019) and Covas and Driscoll (2014) are three main contributions that combine both capital and liquidity requirements to assess their joint impact on lending. All of these papers find that adding liquidity requirements to capital requirements leads to a larger reduction in lending to non-financial agents, in particular for the least liquid and least capitalized institutions. Nevertheless, stylized facts show that private debt has not subdued since the implementation of these new rules.

These papers, however, do not assess the compounded effect of both requirements as compared to the sum of the effects when each requirement is considered individually. Xing et al. (2020) state that, among multiple regulations, which one binds for credit creation depends on banks' balance sheet structure and business models. The latter could influence banks' reliance on relatively more stable liabilities such as customer deposits and on more unstable shorter-term funding such as money market funding. One should also keep in mind that the impact will differ between bank-based and market-based financial systems.

Van den Heuvel (2019) has quantified the effects of the two requirements on the liquidity provisions of banks. This exercise provides a useful indication of the relative macroeconomic costs of these two requirements, although they are taken separately rather than in interaction. The paper concludes that in general capital requirements generate higher costs than liquidity requirements because the former reduces liquidity creation by banks much more than the latter: capital requirements limit the fraction of bank assets that can be financed by issuing deposit-type liabilities. Using US data, the welfare cost of a 10 percent liquidity requirement is found to be equivalent to a permanent loss in consumption of about 0.03 percent. The cost of a similarly-sized increase in the capital requirement is found to be about five times as large.

Empirical papers using Quantitative Impact Studies data provide mixed results. The results found by the BCBS Task Force on Evaluation (BCBS (2022)) from the analysis of the impact of

Basel III reforms on banks' capital and liquidity suggest that the overall level of resilience of the banking sector has increased since the implementation of the Basel reforms, without any increase in the cost of capital. However, the analysis presented in the evaluation report finds few signifcant effects of the interactions between Basel III regulatory ratios on banks' lending growth. Birn et al. (2017) conclude that capital and liquidity requirements are complementary while the Liquidity Coverage Ratio LCR and the Net Stable Funding Ratio NSFR are substitutable. This might appear surprising given they were designed to be complementary, with the LCR having a thirty-day horizon and aimed at ensuring short-term resilience while the NSFR was meant to be more structural, with a one-year horizon and the objective of limiting banks' maturity transformation.

In terms of net effects and broad welfare effects, all the studies investigating the co-existence of capital and liquidity requirements (Boissay and Collard (2016), Adrian and Boyarchenko (2018), Ikeda (2018) as well as Kara and Ozsoy (2020)) suggest that using both regulations would help to achieve the highest attainable level of welfare. The reason is that using both requirements helps to attain a level of stability with the lowest long-term cost to the real economy, where the latter is measured in terms of foregone economic activities due to reduced financial intermediation. According to Boissay and Collard (2016), the net welfare gain in the optimally-regulated economy compared to the unregulated economy corresponds to an increase in permanent annual consumption of 0.66 percent.

Our paper contributes to the existing literature in two ways. It first attempts to jointly model the four main Basel III constraints in a comprehensive but simplified framework based on banks' objective of profit maximisation. As far as we know, this is the first comprehensive attempt of this type in the literature. It also empirically estimates the effect on lending growth of the interactions between the Basel III ratios in a pairwise fashion to shed light on the substituability/complementarity relationship.

3 Theoretical model

3.1 Set-up of the model and assumptions

The main objectives of our partial equilibrium model are to assess how liquidity and capital constraints interact and bear on banks' lending. It is based on a representative bank that maximises its profit under balance sheet, risk-based capital, leverage and liquidity constraints.

Three sources of financing are available to the bank: Tier 1 equity capital, denoted K, remunerated at the cost of capital $\tilde{r^k}$, assumed to integrate costs of banking capital adjustment as well as investors' dividends; deposits D, remunerated at the rate $\tilde{r^d}$; and bonds B, whose interest rate is $\tilde{r^b}$.

There are two items on the asset side: risky loans L, with a long-term maturity and a return $\tilde{r^l}$; and marketable securities S, considered as the only high quality liquid and non-risky assets, with a return equal to $\tilde{r^s}$.

The structure of a bank's balance sheet is as follows:

Returns are assumed to be exogenous and stochastic. They are thus denoted with a $\tilde{r}$. We

Table 1: Structure of the bank's balance sheet

$Assets = A$		Liabilities =LBT	
L	$\tilde{r^l}$	D	$\tilde{r^d}$
S	$\tilde{r^s}$	B	$\tilde{r^b}$
		K	$\tilde{r^k}$
$Total = A$		$Total = LBT = A$	

assume the following inequalities: $E(\tilde{r^s}) < E(\tilde{r^d}) < E(\tilde{r^b}) < E(\tilde{r^l}) < E(\tilde{r^k})$, with equity providing the highest rate of return as capital investors require a higher compensation for the risk they take. Likewise, loans also display a high rate of return due to the associated credit risk. By contrast, marketable securities are the safest assets and thus feature the lowest rate of return.

Bank's profit. The bank is assumed to maximise its profits adjusted with the cost of capital. Likewise, the bank behaves as a mean-variance investor with risk aversion coefficient ρ and a risk-return arbitrage term as in Freixas and Rochet (2008). Although the cost of capital is not included in the calculation of the bank's profits, it has to be incorporated into the optimisation function as the bank takes into account this cost when it carries out its capital planning.

$$\begin{aligned} \max_{S,L,D,B,K} E(\pi_{adj}) &= \tilde{r^l}L + \tilde{r^s}S - \tilde{r^d}D - \tilde{r^b}B - \tilde{r^k}K - \frac{\rho}{2}(\sigma^2_{\tilde{r^s}}S^2 + 2\sigma_{\tilde{r^s}\tilde{r^l}}SL + \sigma^2_{\tilde{r^l}}L^2 + \sigma^2_{\tilde{r^d}}D^2 \\ &+ 2\sigma_{\tilde{r^d}\tilde{r^l}}DL + 2\sigma_{\tilde{r^d}\tilde{r^s}}DS + \sigma^2_{\tilde{r^b}}B^2 + 2\sigma_{\tilde{r^s}\tilde{r^b}}SB + 2\sigma_{\tilde{r^l}\tilde{r^b}}LB + 2\sigma_{\tilde{r^d}\tilde{r^b}}DB) \end{aligned} \tag{1}$$

with $\sigma^2_{\tilde{r^s}}$, $\sigma^2_{\tilde{r^l}}$, $\sigma^2_{\tilde{r^d}}$ and $\sigma^2_{\tilde{r^b}}$ being the variance of returns on securities, loans, deposits and bonds, respectively, and $\sigma_{\tilde{r^s}\tilde{r^l}}$, $\sigma_{\tilde{r^d}\tilde{r^l}}$, $\sigma_{\tilde{r^d}\tilde{r^s}}$, $\sigma_{\tilde{r^s}\tilde{r^b}}$, $\sigma_{\tilde{r^l}\tilde{r^b}}$ and $\sigma_{\tilde{r^d}\tilde{r^b}}$ the covariance between each pairwise item.

Bank's constraints. The bank faces multiple regulatory and accounting constraints. In what follows, the different categories of asset and liability items will be assigned different weights reflecting the risk-oriented framework of regulatory requirements, depending on their credit and liquidity riskiness as well as their maturity.

The first constraint is a balance sheet constraint:

$$K + D + B = L + S \tag{2}$$

which can be rearranged in:

$$B = L + S - K - D \tag{3}$$

In addition, the bank faces a risk-based capital constraint whereby it has to hold enough Tier 1 capital in proportion to the sum of its risk-weighted assets, with riskier assets being assigned higher capital requirements. The bank's risk-based capital constraint is the following:

$$\frac{K}{\theta_L.L + \theta_S.S} \geq \overline{K} \tag{4}$$

with $\overline{K}$ being the regulatory minimum Tier 1 capital requirement defined as a proportion of risk-weighted assets within the Basel III framework, θ_L being the regulatory risk weight on risky loans, and θ_S being the regulatory risk weight on marketable securities.

Moreover, the bank has to meet a leverage ratio constraint whereby its amount of Tier 1 capital K must exceed a proportion $\overline{LR}$ of the overall size of its balance sheet (total assets here instead of total exposures to simplify our analysis):

$$\frac{K}{L+S} \geq \overline{LR} \tag{5}$$

Within the Basel III framework, the bank faces two additional regulatory constraints on its liquidity: the Liquidity Coverage Ratio (LCR), which aims at ensuring that banks hold enough liquid assets to cope with net cash outflows on their liabilities over a 30-day horizon in stressed market conditions and without the support of central banks; the Net Stable Funding Ratio (NSFR), aiming at limiting the maturity transformation performed by the bank over a 1-year horizon, by ensuring that long-term assets are financed by stable fundings. Under the LCR requirement, a fraction of liabilities is assumed to be withdrawn. The LCR constraint can be expressed according to the following formula:

$$\frac{\phi S}{l_D.D + l_B.B} \geq \overline{LCR} \tag{6}$$

with ϕ being the regulatory weight applied to the asset S to capture its level of liquidity (and $1-\phi$ thus being the haircut applied to that asset), l_D the outflow rate on deposits and l_B the outflow rate on bond financing. In line with the regulatory weights set in the LCR regulation, the outflow rate on bond financing (l_B) is higher than the outflow rate on deposits (l_D) as bond financing is considered to be more volatile than deposit funding. Therefore, $l_B > l_D$.

Finally, the NSFR requires the bank have enough available stable funding over a one-year horizon to match the funding needs over the same period. The corresponding constraint can be expressed according to the following formula:

$$\frac{K + asf_D.D + asf_B.B}{rsf_S.S + rsf_L.L} \geq \overline{NSFR} \tag{7}$$

with asf_D being the liquidity weight associated with deposit financing, asf_B the liquidity weight associated with bond financing, rsf_S the required financing weight associated with the holding of marketable securities and rsf_L the required financing weight associated with loan holdings. In the same spirit as that of the LCR, the liquidity weight associated in the NSFR regulation with deposit financing (asf_D) is higher than the liquidity weight associated with bond financing (asf_B), as deposits are supposed to be more stable than bond financing. Consequently, $asf_D > asf_B$.

The table below summarizes the value of the regulatory parameters used in our model.

3.2 The programme of the bank

We are interested in identifying the determinants of the stock of loans L. The bank maximises its profit adjusted with the cost of capital. However, K is set outside the model to a large extent as we assume the bank targets a capital amount taking into account a management buffer m

Table 2: Value of regulatory parameters

Parameters	Regulatory ratio	Regulatory value
$\overline{K}$	Tier1 capital ratio	6%
$\overline{LR}$	Leverage ratio	3%
$\overline{LCR}$	LCR	100%
$\overline{NSFR}$	NSFR	100%
ϕ	LCR	98% 1/
l_D	LCR	10% 1/
l_B	LCR	36% 1/
asf_D	NSFR	94% 1/
asf_B	NSFR	19% 1/
$rsff_S$	NSFR	8% 1/
asf_L	NSFR	62% 1/

Source: BCBS

Note: 1/Average value for the 6 largest banks at end-Dec. 2021

above the minimum capital requirement and expressed in percentage, determined by market constraints, maximum distribution amount thresholds, delays and costs of banking capital adjustment. Therefore, we assume the following equality:

$$K^* = \gamma \overline{K}(\theta_L.L + \theta_S.S) \tag{8}$$

with $\gamma \geq 1$, $\gamma = 1 + m$ and $m > 0$. As K^* is directly proportionate to risk-weighted assets ($\theta_L.L + \theta_S.S$), the fact that we impose its value sets the bank's balance sheet size to a large extent. Indeed, the bank would be able to increase its market funding or its deposits but would then face its leverage constraint.

Therefore, we are left with 3 variables of choice for the bank, which are balance sheet variables as the bank is assumed to choose quantities: S, L, and D, with solutions being expressed as a function of K. The issuance of bonds is thus assumed to adjust ex post to balance the balance sheet through the quantity B. It should be noted that our price variables $(\tilde{r^s}, \tilde{r^d}, \tilde{r^b}, \tilde{r^l}, \tilde{r^k})$ could be considered as endogenous as, for example, a higher amount of capital would be expected to result in a decline in the bank's funding costs (Admati and Hellwig (2013), Gambacorta and Shin (2018)). However, endogenising the price variables would make our model overly complex. For that reason, we decided to keep them as exogenous.

$$\begin{aligned} \max_{S,L,D,B,K} E(\pi_{adj}) \quad = \quad & \tilde{r^l}L + \tilde{r^s}S - \tilde{r^d}D - \tilde{r^b}B - \tilde{r^k}K - \frac{\rho}{2}(\sigma^2_{\tilde{r^s}}S^2 + 2\sigma_{\tilde{r^s}\tilde{r^l}}SL + \sigma^2_{\tilde{r^l}}L^2 + \sigma^2_{\tilde{r^d}}D^2 \\ & + 2\sigma_{\tilde{r^d}\tilde{r^l}}DL + 2\sigma_{\tilde{r^d}\tilde{r^s}}DS + \sigma^2_B B^2 + 2\sigma_{\tilde{r^s}\tilde{r^b}}SB + 2\sigma_{LB}LB + 2\sigma_{DB}DB) \end{aligned} \tag{9}$$

subject to the following constraints:

$$K = L + S - D - B \tag{10}$$

$$\phi S \geq \overline{LCR}(l_D.D + l_B.B) \tag{11}$$

$$K + asf_D.D + asf_B.B \geq \overline{NSFR}(rsf_S.S + rsf_L.L) \tag{12}$$

$$\text{and} \quad K \geq \overline{LR}(L + S) \tag{13}$$

We can then associate the following Lagrangian function, $\mathcal{L}$:

$$\begin{aligned} \mathcal{L}(S, L, D, K, \lambda_1, \lambda_2, \lambda_3) \;=\; & \tilde{r^l}L + \tilde{r^s}S - \tilde{r^d}D - \tilde{r^b}(L + S - K - D) - \tilde{r^k}K - \frac{\rho}{2}(\sigma^2_{\tilde{r^s}}S^2 + 2\sigma_{\tilde{r^s}\tilde{r^l}}SL + \sigma^2_{\tilde{r^l}}L^2 \\ & + \sigma^2_{\tilde{r^d}}D^2 + 2\sigma_{\tilde{r^d}\tilde{r^l}}DL + 2\sigma_{\tilde{r^d}\tilde{r^s}}DS + \sigma^2_B(L + S - K - D)^2 + 2\sigma_{\tilde{r^s}\tilde{r^b}}S(L + S - K - D) \\ & + 2\sigma_{LB}L(L + S - K - D) + 2\sigma_{DB}D(L + S - K - D)) \\ & + \lambda_1(\phi S - \overline{LCR}(l_D.D + l_B.B)) \\ & + \lambda_2(K + asf_D.D + asf_B.B - \overline{NSFR}(rsf_S.S + rsf_L.L)) \\ & + \lambda_3(K - \overline{LR}(L + S)) \end{aligned} \tag{14}$$

with λ_1, λ_2, and λ_3 being the Lagrange multipliers of the LCR, NSFR, and leverage constraints, respectively.

After plugging the balance sheet equality constraint into the Lagrangian and substituting the value of K, we get the final form of the Lagrangian function:

$$\begin{aligned} \mathcal{L}(S, L, D, \lambda_1, \lambda_2, \lambda_3) \;=\; & \tilde{r^l}L + \tilde{r^s}S - \tilde{r^d}D - \tilde{r^b}B - \tilde{r^k}(S + L - D - B) - \frac{\rho}{2}(\sigma^2_{\tilde{r^s}}S^2 + 2\sigma_{\tilde{r^s}\tilde{r^l}}SL + \sigma^2_{\tilde{r^l}}L^2 \\ & + \sigma^2_{\tilde{r^d}}D^2 + 2\sigma_{\tilde{r^d}\tilde{r^l}}DL + 2\sigma_{\tilde{r^d}\tilde{r^s}}DS + \sigma^2_B B^2 + 2\sigma_{\tilde{r^s}\tilde{r^b}}SB \\ & + 2\sigma_{LB}LB + 2\sigma_{DB}DB) \\ & + \lambda_1(\phi S - \overline{LCR}(l_D.D + l_B.B)) \\ & + \lambda_2(S + L - D - B + asf_D.D + asf_B.B - \overline{NSFR}(rsf_S.S + rsf_L.L)) \\ & + \lambda_3(S + L - D - B - \overline{LR}(L + S)) \end{aligned} \tag{15}$$

After the resolution of the optimisation programme, we show that the constraints interact with each other as the introduction of the NSFR for example reduces the degree of tightness of the LCR constraint multiplier λ_1, meaning that it helps the bank to fulfill its other liquidity requirement (see Annex). The introduction of the two other constraints (Tier 1 risk-based capital ratio and leverage ratio) is also shown to reduce the value of λ_1.

3.3 Conditions determining which constraints bind

As stated by Xing et al. (2020), among multiple regulations, which one binds basically depends on bank's balance sheet structure. A regulatory ratio is more binding than another if the bank has a lower excess of available resources or if it should reduce its balance sheet more to meet it. In other words, it is more binding if the maximum amount of loans under this constraint is lower than under another constraint. Therefore, let's first determine the maximum amounts of loans that are allowed under the risk-based capital constraint and the leverage constraint and compare these two amounts.

$$(13) \Leftrightarrow L^{max}_{Tier1} = \frac{K}{\gamma\overline{K}\theta_L} - \frac{\theta_S}{\theta_L}S \tag{16}$$

$$(14) \Leftrightarrow L^{max}_{Lev} = \frac{K}{\overline{LR}} - S \tag{17}$$

$$(16) + (17) \Leftrightarrow L^{max}_{Tier1} < L^{max}_{Lev} \Leftrightarrow \frac{K}{\gamma\overline{K}\theta_L} < \frac{K}{\overline{LR}} \tag{18}$$

$$\Leftrightarrow \theta_L > \frac{\overline{LR}}{\gamma\overline{K}} \tag{19}$$

Within this framework, for a given capital level, the interactions between regulatory parameters indicate that the maximum amount of loans allowed under the risk-based capital ratio is lower than under the leverage ratio (i.e. the risk-based capital ratio is more binding than the leverage ratio) if the loans' average risk weight θ_L exceeds a certain threshold. This confirms that the answer to the question: "which constraint binds?" cannot be absolute but depends on the structure of the bank's balance sheet, the riskiness of its assets and the size of the management buffer m (with $\gamma = 1 + m$). Figure 1 below provides a graphical illustration of the relative bindingness of the risk-based capital ratio and the leverage ratio regarding the maximum amount of loans, focusing on the threshold value of the loan risk density (θ_L), for given values of K, S and θ_S. It shows that for a low value of θ_L (i.e. $\theta_L < \frac{\overline{LR}}{\gamma\overline{K}}$), the line corresponding to the Tier 1 risk-based capital constraint is always above the line corresponding to the leverage constraint and the slope of the leverage ratio line is steeper than that of the Tier 1 risk-based capital constraint. Therefore, for these values of θ_L, the leverage ratio appears to be the binding constraint and acts as a backstop, in line with its assigned regulatory function.

Figure 2 presents the same illustration, but for high values of θ_L (i.e. $\theta_L > \frac{\overline{LR}}{\gamma\overline{K}}$). In this case, the Tier 1 risk-based capital constraint is binding; however, as S increases (or L decreases), the leverage constraint becomes binding. Based on the current values of regulatory requirement parameters, the theshold value of θ_L given by Inequality 19 reaches between 50 percent and 62.5 percent, depending on whether we retain a minimum risk-based capital requirement ratio of 6 percent or 8.5 percent (if we include the capital conservation buffer of 2.5 percent, on top of the minimum capital requirement ratio of 6 percent).

Figure 1: Comparison between the maximum amount of loans allowed under the risk-based capital ratio and the leverage ratio - low value of θ_L

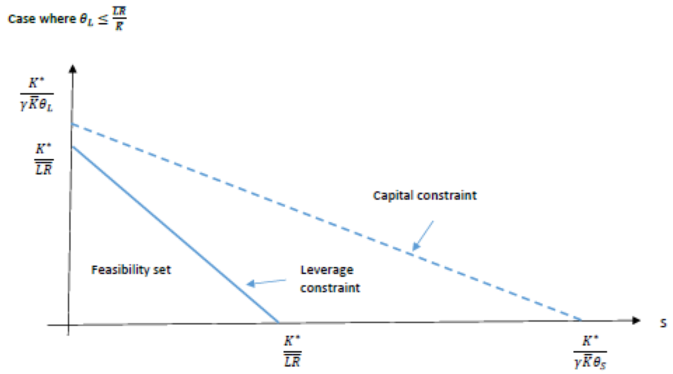
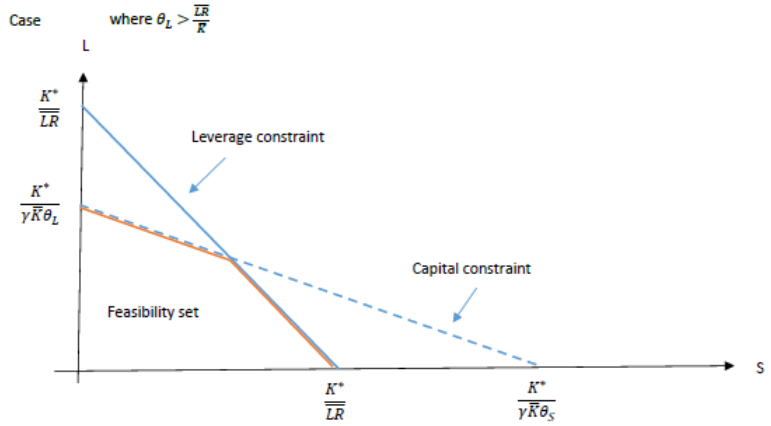


Figure 2: Comparison between the maximum amount of loans allowed under the risk-based capital ratio and the leverage ratio - high value of θ_L



For a given capital level, we can also determine the maximum amounts of loans that are allowed under the LCR and the NSFR and compare these two amounts. We can derive the following inequality from the LCR constraint (6):

$$(6) \Leftrightarrow S \geq \frac{\overline{LCR}}{\phi}(l_D D + l_B B) \tag{20}$$

Using the balance sheet equality constraint, we can deduct the following expression of L_{LCR}^{max} as a function of the items on the liability side:

$$(10+20) \Leftrightarrow L_{LCR}^{max} = (1 - \frac{\overline{LCR}.l_D}{\phi})D + (1 - \frac{\overline{LCR}.l_B}{\phi})B + K^* \tag{21}$$

From the NSFR constraint inequality (12) and the balance sheet equality constraint, we can derive the following expression of L_{NSFR}^{max}:

$$(10+12) \Leftrightarrow L_{NSFR}^{max} = (\frac{\frac{asf_D}{NSFR} - rsf_S}{rsf_L - rsf_S})D + (\frac{\frac{asf_B}{NSFR} - rsf_S}{rsf_L - rsf_S})B + (\frac{\frac{1}{NSFR} - rsf_S}{rsf_L - rsf_S})K^* \tag{22}$$

These equations show that L_{LCR}^{max} and L_{NSFR}^{max} positively depend on the resources the bank has at its disposal. We thus see that the liquidity constraints do not limit the amount of loans per se but determine the liability structure of the bank by favouring own funds in the first place, then deposits and lastly market funding. By contrast, the risk-based capital and the leverage constraints set limits determining the maximum amount of loans. The optimal amount will depend on funding costs and result from the bank's profit maximisation programme.

$$(21) + (22) \Leftrightarrow L_{LCR}^{max} > L_{NSFR}^{max}$$

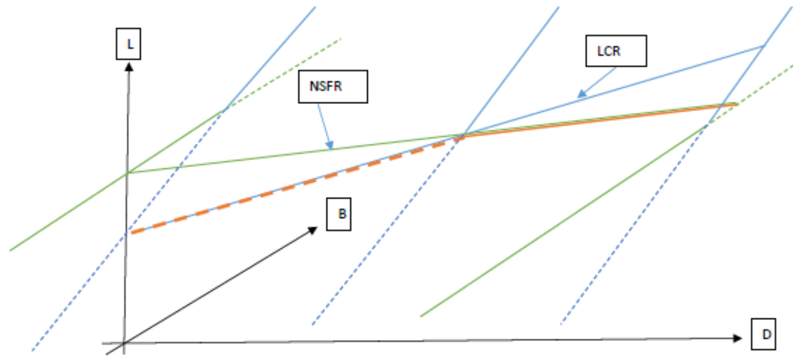
$$\Leftrightarrow (1 - \frac{\overline{LCR}.l_D}{\phi})D + (1 - \frac{\overline{LCR}.l_B}{\phi})B + K^* > (\frac{\frac{asf_D}{NSFR} - rsf_S}{rsf_L - rsf_S})D + (\frac{\frac{asf_B}{NSFR} - rsf_S}{rsf_L - rsf_S})B + (\frac{\frac{1}{NSFR} - rsf_S}{rsf_L - rsf_S})K^* \tag{23}$$

$$\Leftrightarrow rsf_L > \frac{\frac{K^*}{NSFR} + (\frac{asf_D}{NSFR} - \frac{\overline{LCR}.l_D.rsf_S}{\phi})D + (\frac{asf_B}{NSFR} - \frac{\overline{LCR}.l_B.rsf_S}{\phi})B}{K^* + (1 - \frac{\overline{LCR}.l_D}{\phi})D + (1 - \frac{\overline{LCR}.l_B}{\phi})B} \tag{24}$$

As can be seen, the interactions between the LCR and NSFR parameters give a threshold value of rsf_L above which the maximum amount of loans allowed by the NSFR constraint is lower than under the LCR constraint (i.e. the NSFR is more binding than the LCR). Figure 3 below provides a graphical illustration of the relative bindingness of the LCR and the NSFR regarding the maximum amount of loans, for given values of K, S, and D. We can see that the two liquidity constraints can be represented by two increasing geometric planes for a given capital target. They intersect and their intersection corresponds to a straight line. Moreover, the $\gamma\overline{K}$ intercept is increasing with the NSFR constraint.

Let's now determine the threshold value of θ_L above which the maximum amount of loans allowed by the risk-based capital constraint is lower than under the LCR constraint.

Figure 3: Comparison between the maximum amount of loans allowed under the LCR and the NSFR



$$(16) + (21) \Leftrightarrow L^{max}_{Tier1} < L^{max}_{LCR} \Leftrightarrow \frac{K}{\gamma \overline{K}} - \theta_S S < \theta_L.((1 - \frac{\overline{LCR}.l_D}{\phi})D + (1 - \frac{\overline{LCR}.l_B}{\phi})B + K^*) \quad (25)$$

$$(25) \Leftrightarrow \theta_L > \frac{\frac{K}{\gamma \overline{K}} - \theta_S S}{(1 - \frac{\overline{LCR}.l_D}{\phi})D + (1 - \frac{\overline{LCR}.l_B}{\phi})B + K^*} \quad (26)$$

Therefore, the value of θ_L must be high enough for the risk-based capital constraint to be more binding than the LCR constraint.

Similarly, the condition on the degree of liquidity of marketable securities ϕ under which the LCR constraint would be more binding than the leverage constraint would be the following:

$$(17) + (21) \Leftrightarrow L^{max}_{LCR} < L^{max}_{Lev} \Leftrightarrow (1 - \frac{\overline{LCR}.l_D}{\phi})D + (1 - \frac{\overline{LCR}.l_B}{\phi})B + K^* < \frac{K}{\overline{LR}} - S \quad (27)$$

$$\Leftrightarrow \phi < \frac{\overline{LCR}.l_D.D + \overline{LCR}.l_B.B}{K^*(1 - \frac{1}{\overline{LR}}) + S + D + B} \quad (28)$$

We can note that the relative bindingness of the LCR compared to the leverage ratio does not depend on parameters related to the loan portfolio.

Then, let's determine the balance sheet conditions for the NSFR constraint to be more binding than the risk-based capital constraint. As both ratios depend on parameters related to loans, rsf_L and θ_L respectively, their ratio determines the relative bindingness of the two ratios one compared to another.

$$(16) + (22) \Leftrightarrow L^{max}_{NSFR} < L^{max}_{Tier1} \quad \Leftrightarrow \quad (\frac{\frac{asf_D}{\overline{NSFR}} - rsf_S}{rsf_L - rsf_S})D + (\frac{\frac{asf_B}{\overline{NSFR}} - rsf_S}{rsf_L - rsf_S})B + (\frac{\frac{1}{\overline{NSFR}} - rsf_S}{rsf_L - rsf_S})K^* < \frac{\frac{K}{\gamma \overline{K}} - \theta_S S}{\theta_L} \quad (29)$$

$$\Leftrightarrow \frac{rsf_L - rsf_S}{\theta_L} > \frac{(\frac{asf_D}{\overline{NSFR}} - rsf_S)D + (\frac{asf_B}{\overline{NSFR}} - rsf_S)B + (\frac{1}{\overline{NSFR}} - rsf_S)K^*}{\frac{K}{\gamma \overline{K}} - \theta_S S} \quad (30)$$

Finally, the condition under which the NSFR constraint would be more binding than the leverage constraint would be the following:

$$(17) + (22) \Leftrightarrow L^{max}_{NSFR} < L^{max}_{Lev} \quad \Leftrightarrow \quad \frac{(\frac{asf_D}{NSFR} - rsf_S)D + (\frac{asf_B}{NSFR} - rsf_S)B + (\frac{1}{NSFR} - rsf_S)K^*}{rsf_L - rsf_S} < \frac{K}{\overline{LR}} - S \tag{31}$$

$$\Leftrightarrow rsf_L > \frac{(\frac{asf_D}{NSFR} - rsf_S)D + (\frac{asf_B}{NSFR} - rsf_S)B + (\frac{1}{NSFR} - rsf_S)K^*}{\frac{K}{\overline{LR}} - S} + rsf_S \tag{32}$$

From model to data. Having set the conditions under which the different regulatory constraints are weighing on the maximum amount of loans, we now move to the data analysis. The main point of interest will be the interactions between the different requirements in an empirical model explaining lending growth. This will allow us to illustrate the nature of the relationship between two ratios from the perspective of their effects on lending growth. We will estimate our main expression of the rate of growth of L_t given by Equation (47) presented in Annex. The theoretical model also shows that the riskiness of loans and uncertainty are important determinants of which regulatory constraint binds compared to another. As the degree of riskiness of a loan can vary across the financial and economic cycle, our empirical model will also include macrofinancial and macroeconomic variables.

4 Empirical analysis

4.1 Data and descriptive statistics

4.1.1 Data

Our estimations use data from multiple sources and cover the period from 2014 to 2021, on a quarterly basis. We first used the regulatory reporting databases (FINREP, COREP) comprising balance sheet and prudential data on French banks on a consolidated basis for our empirical analysis. This dataset was merged with data on banks' legal information and affiliations ("Etat civil" database) in order to link banks' lending growth with banks' legal form and kept only credit institutions in the final sample. Given its very recent implementation at the European level (June 2021), NSFR data is taken from the Basel Committee's Quantitative Impact Studies (QIS) exercise for which the ACPR collects data on a semi-annual basis for the 6 main French banking groups. Macroeconomic control variables were taken from Eurostat and financial variables from Bloomberg.

As we are mostly interested in institutions that have deposit and lending activity, we removed financial firms from the sample and only kept commercial banks, mutual banks, specilised credit institutions and heads of banking groups. We end up with a panel dataset comprising around 2,300 observations covering 120 banks and 32 periods. Moreover, due to the recent implementation of the NSFR, we had to distinguish between two samples: a full sample of banks used for the estimations involving regulatory ratios other than the NSFR, and a sample of the six largest banks reporting their NSFR as part of the QIS exercise for the same regressions involving the NSFR.

4.1.2 Descriptive statistics

This subsection provides descriptive statistics about our dependent variable, namely the year-on-year growth rate of loans to the non-financial private sector (households and non-financial corporations) , as well as other bank-specific variables, including regulatory ratios and the average risk-weight, described in Table 2. Loans to households and non-financial corporations are indeed more representative of the financing of the economy and, given the risk and liquidity weights they carry, can be expected to be more sensitive to interactions between regulatory ratios than total loans. As regards regulatory ratios, there is a reporting asymmetry, with minimum values close to the regulatory threshold, although rarely below, and explosive maximum values due to some very specific business models. For these reasons, we kept all minimum values on regulatory ratios that did not constitute outliers, but rather banks for which the regulatory requirements may be binding, which is the focus of this study. Conversely, we excluded the maximum values above the 95th percentile for the two capital ratios, and above the 75th percentile for the more volatile liquidity coverage ratio[1]. While values below regulatory minima are in theory not possible, the observation of such values may occur if the ratios are not enforced at their fully-loaded value at the observation date.

It should be noted that the different regulatory ratios have been reported and enforced at various dates. The risk-based Tier 1 capital ratio (designed as "Tier 1 ratio" in the table for the sake of conciseness) was the only ratio reported and enforced at the start of our period of estimation. The leverage ratio and the LCR have been reported since 2016Q3[2] while fully enforced in June 2021 and January 2018, respectively. Finally, the NSFR has been reported in the QIS exercise since 2010 and enforced since June 2021. During the period of observation or phase-in, banks started to prepare and to adjust their balance sheets. However, during such periods, it is hard to conclude on the effects of interactions or on the bindingness of the different ratios.

Given the wide distribution of the bank-specific control variables (size, loan share, NPL ratio), we decided to winsorise these variables at the 5th and 95th percentile of their distribution, in order to address the misreporting issues and eliminate outliers. We also dropped banks with less than 5 observations (quarters) in the sample.

Table 3 shows that the regulatory ratios are little binding on average as their sample mean is always largely above the minimum requirements. However, a look at the minimum values shows that some banks may not have fulfilled some ratios at specific dates. Moreover, the value of the average risk weight of 43 percent, as compared to the threshold value of 50 or 62.5 percent emphasised in the theoretical model, tends to indicate that on average, the leverage ratio constraint is more binding than the Tier 1 risk-based capital constraint.

Figure 4 displays the evolution of the growth rate of the aggregate loans to the non-financial

[1] In particular, our sample includes clearing houses that have the status of credit institutions even though their activity is not mainly a maturity transformation activity and their business model is characterised by very low net cash outflows, resulting in very high LCR levels. As it is not possible to identify all these "artificial" credit institutions, we apply this more specific cleaning procedure. The NSFR was not adjusted because data are only available on six banks and no outlier was identified.

[2] It is possible to build a close proxy of the leverage ratio before this date by calculating the Tier 1 capital-to-total assets ratio, though.

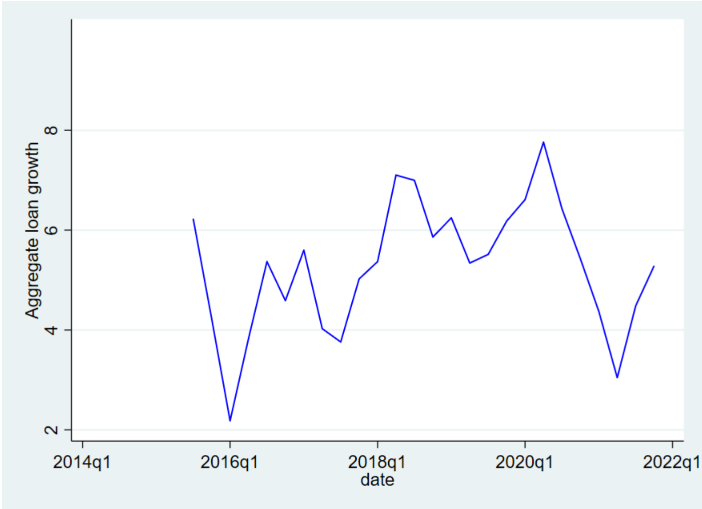
Table 3: Descriptive statistics on main bank-specific variables (in %) (after cleaning and winsorization)

Variable	Obs.	Mean	Std. Dev.	Min	Max
Lending growth (nonfinancial private sector)	2,881	6.23	5.68	-6.37	19.57
Tier 1 ratio	3,718	17.79	4.77	6.08	32.05
Tier 1 buffer	3,719	14.08	5.82	-3.36	29.8
Leverage ratio	3,532	7.30	2.68	.10	16.38
LCR	833	149.79	38.44	.69	253.50
NSFR	270	105.32	14.25	75.90	142.96
Average risk-weight	3,397	43.13	21.84	5.57	242.86
Size	3,426	.87	2.39	0	16.30
Business model	3,426	59.13	20.08	3.35	83.86
NPLR	3,403	2.73	1.43	.78	6.36

Sources: ACPR, Authors' calculations.

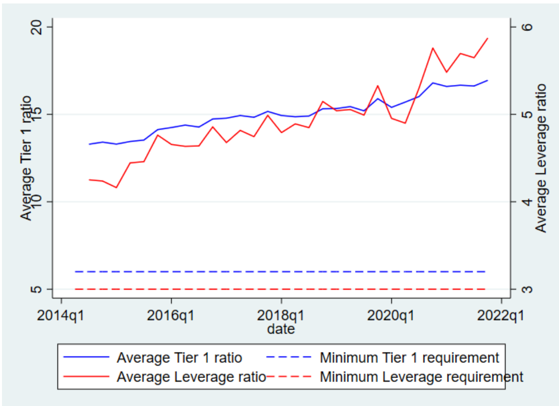
private sector. The constantly positive lending growth over the period, despite various exogenous shocks such as the 2020-21 Covid-19 pandemic, is a first indication that the implementation of Basel III did not entail a credit crunch. On Figure 5, both the average solvency and leverage ratios displayed rising trends from 2014/2016, with a large capital headroom between the average values and the minimum requirements (dashed lines). Finally, Figure 7 shows that on average, the means of the LCR and NSFR have always been above the minimum requirements (dashed lines). Moreover, both ratios have been exhibiting a clear upward trend since 2014/2015, very slightly reversed by the 2020/2021 health crisis. This may reflect the impact of the exceptional liquidity provision measures taken by the European Central Bank during this period or a form of banks' reluctance to use their liquidity buffers in times of crisis, possibly due to the fear of the stigma effect.

Figure 4: Aggregate lending growth on a year-on-year basis 2014-2021 (in %)



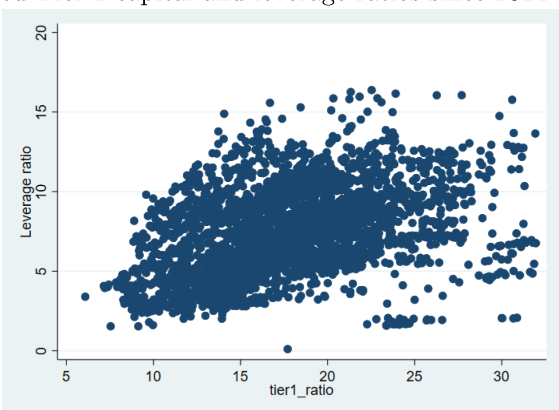
Source: ACPR

Figure 5: Risk-based capital Tier 1 ratio and leverage ratio since 2014 (in %)



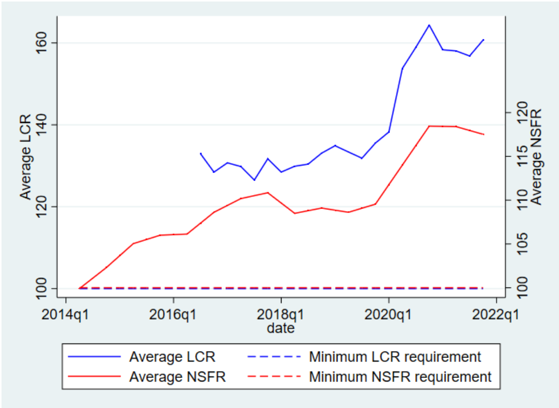
Source: ACPR

Figure 6: Risk-based Tier 1 capital and leverage ratios since 2014 (in %)- Scatter plot



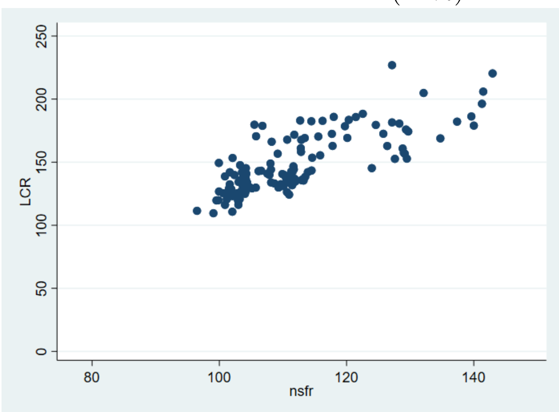
Source: ACPR

Figure 7: LCR and NSFR since 2014 (in %)



Source: ACPR

Figure 8: LCR and NSFR since 2014 (in %)- Scatter plot



Source: ACPR

Table 4 displays the correlation coefficients between all the bank-specific variables composing our model. A positive and significant correlation coefficient can be observed between each regulatory ratio, suggesting that if conflicting evolutions have occurred, they have not prevented regulatory ratios from improving. The highest correlation can be noticed between the LCR and the NSFR (coefficient of 0.77), raising questions about the potential redundancy between these ratios, in line with the findings of Bolton et al. (2019). The correlation is the lowest between the risk-based capital ratio (designed as "Tier 1 ratio" in the table for the sake of conciseness) and the LCR (0.03). The Tier 1 management buffer above risk-based capital requirement (designed as "Tier 1 buffer" in the table for the sake of conciseness) displays a high correlation with the risk-based Tier 1 capital ratio (0.66) but a negative correlation with the LCR (-0.14).

As regards the bank-specific control variables, we can note that the size variable exhibits a negative correlation coefficient with every regulatory ratio. This may indicate an optimisation of the value of the ratios, as capital is costly for the bank, or a larger risk-taking behaviour on the part of larger banks, which can be due to their more diversified funding sources or reflect the implicit "too big to fail" subsidy. The signs and significance of the correlation coefficients vary for the loan share variable and the change in the Non Performing Loan (NPL) ratio. Surprisingly, lending growth exhibits a significantly positive growth with only one regulatory ratio: the NSFR. In this context, the empirical analysis will enable us to better assess the effect of these interactions between regulatory ratios on lending growth.

Table 4: Correlation between bank-specific variables (in %)

Variables	Lending growth	Tier 1 ratio	Management buffer	Leverage ratio	LCR	NSFR	Size	Loan share	Change in NPLR
Lending growth	1.0000								
Tier 1 ratio	0.0298	1.0000							
	(0.1132)								
Management buffer	-0.0137	0.6583***	1.0000						
	(0.4670)	(0.0000)							
Leverage ratio	-0.0296	0.4095***	0.2873***	1.0000					
	(0.1175)	(0.0000)	(0.0000)						
LCR	-0.0190	0.0330***	-0.1430***	0.1900***	1.0000				
	(0.6349)	(0.3597)	(0.0001)	(0.0000)					
NSFR	0.4306***	0.4867***	-0.0783	0.2391***	0.7739***	1.0000			
	(0.0000)	(0.0000)	(0.2958)	(0.0012)	(0.0000)				
Size	-0.1003***	-0.2272***	-0.2252***	-0.3536***	-0.0927**	-0.6790***	1.0000		
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0176)	(0.0000)			
Loan share	0.1778***	0.0661***	0.0538***	0.4196***	-0.2299***	-0.0266	-0.3161***	1.0000	
	(0.0000)	(0.0001)	(0.0018)	(0.0000)	(0.0000)	(0.7234)	(0.0000)		
Change in NPLR	0.0186	0.0877***	0.0274	-0.1546***	0.1090***	0.4023***	0.0306*	-0.1424***	1.0000
	(0.3176)	(0.0000)	(0.1435)	(0.0000)	(0.0062)	(0.0000)	(0.1002)	(0.0000)	

Sources: ACPR, Authors' calculations.

Note: P-values in parentheses

*** p<0.01, ** p<0.05, * p<0.1

4.2 Empirical model set-up

We now want to estimate the determinants of lending growth, building on the predictions of our theoretical model presented in Annex and on the main findings of the economic literature emphasizing the role of banks' solvency, liquidity and risk aversion as main factors of credit supply. In particular, we want to shed light on the effects of regulatory ratios and of their interactions, to assess the extent to which they have an impact on loan supply and whether they act as substitutes or complements on lending growth. To that end, we estimated a panel model with fixed effects. It was not possible to estimate a pure difference-in-difference model due to the difficulty of establishing treated and control groups, to the low number of observations of ratios below minimum requirements and to the different implementation dates from one ratio to another. Our dependent variable is the year-on-year growth rate of loans to households and non-financial corporations as we want to estimate Equation (47) presented in the theoretical Annex. The absence of large bank mergers during the period of observation avoids the need to adjust the underlying loan series. Our main explanatory variables will be the lagged growth rate of the risk-weighted assets, as well as the interaction terms between the regulatory ratios over regulatory minima in a pairwise fashion, as a proxy for the expression of Γ given by the theoretical model, derived in the annex. The model will also include a range of control variables such as the lagged values of each regulatory ratio, interaction terms between their squared values, other bank-specific variables, as well as macroeconomic and financial variables. Every bank-specific variable is lagged by one year (four periods) to avoid endogeneity issues. By doing so, we include the four regulatory ratios in our models but we make them interact with each other two by two as factors of credit supply.

Our first aggregate financial risk variable is the change in the Euro Stoxx 50 Volatility ***V2X*** Index, taken from Bloomberg, an indicator for risk aversion in the euro area financial markets that also reflects liquidity in European markets, as these two components are often linked. We expect a negative sign on the coefficient of this variable as an increase in European investors' risk aversion should translate into an increase in banks' risk aversion, which should lead them to limit their loan supply. We also used the change in the 3-month Euribor rate, taken as an indicator of monetary policy transmission and credit market conditions. We expect a negative sign on the coefficient of this variable because an increase in the Euribor rate would result in higher funding costs for banks, which would translate at some point into higher lending rates, and thus a lower loan growth due to demand effects.

Macroeconomic variables are the changes in ***GDP growth***, and the ***inflation rate*** in the euro area on a year-to-year basis, taken from Eurostat (European Statistical Office). They are meant to capture credit demand effects. The euro area perimeter is justified by the international activity of French banks, mainly focused on the euro area. The two variables are expected to have a positive effect on lending growth as the borrowing capacity of economic agents improves in good economic times and credit demand increases in times of higher inflation.

Bank-specific control variables were taken from the regulatory reporting FINREP database, with a quarterly frequency. They were all lagged to avoid endogeneity issues and winsorised at the 5th and 95th percentile of their distribution to get rid of outlier values at both ends of the distribution:

- the ***size*** variable corresponds to the market share of the bank in terms of assets. The ratio of each bank's assets to the mean total assets is meant to avoid spurious correlation stemming from a time trend in banks' assets. The sign of the coefficient of this variable is a priori ambiguous. On the one hand, bigger banks may have more room to increase their loan supply due to their diversified access to funding and their lower risk aversion, in line with the too-big-to-fail implicit subsidy. On the other hand, smaller banks may have a strategy of market share gains and thus tend to display a higher lending growth rate to correct the gap;

- the year-on-year change in the ***non-performing loan (NPL)*** ratio is used as a risk variable. We expect a negative sign on the coefficient of this variable as a higher level of non-performing loans implies a more prudent lending strategy by the bank;

- the ***loan share*** variable captures the bank's business model, built as the ratio of transactions with non-financial customers (loans to households and non-financial corporations) to total assets. The sign of this variable is uncertain. On the one hand, loans to non-financial customers are not considered as liquid on the asset side and a high share of them in a bank's balance sheet might thus weigh on its liquidity ratio and limit its loan supply. On the other hand, banks whose business model is directly associated with lending to the non-financial customers might have greater ability to increase their loan supply as they know better these customers and have a more stable relationship than other banks.

Our model was estimated on a quarterly basis. Therefore, we calculated simple quarterly averages for series having a higher frequency, namely financial variables and the consumer price index.

We also introduced bank individual fixed effects to capture banks' unobserved and time invariant individual heterogenity, as well as time fixed effects to capture time-varying global factors not already captured by the other variables.

The reduced form of our equations specification can be read as follows for bank i:

$$\begin{aligned}\Delta L_{i,t} &= \alpha + \beta_1(Reg_{1_{i,t-4}} * Reg_{2_{i,t-4}}) + \beta_2 Reg_{1_{i,t-4}} + \beta_3 Reg_{2_{i,t-4}} + \beta_4(Reg^2_{1_{i,t-4}} * Reg^2_{2_{i,t-4}}) \\ &\quad + \lambda X_t + \gamma Z_{i,t-4} + \sigma_i + \eta_t + \epsilon_{i,t} \qquad (33)\end{aligned}$$

where $\Delta L_{i,t}$ is our depending variable, namely the year-on-year growth rate of loans to households and non-financial corporations; Reg_1 and Reg_2 are the values of regulatory ratios; $Reg_1 * Reg_2$ is the interaction term between the two ratios; $Reg_1^2 * Reg_2^2$ is the interaction term between the squared values of two ratios meant to capture possible non-linear effects; X_t is a vector of exogenous explanatory variables including our aggregate financial risk variables i.e. the year-on-year change in V2X index, the year-on-year change in the 3-month Euribor and macroeconomic variables (change in GDP growth, the inflation rate and the unemployment rate in the euro area) ; Z_{t-4} is a vector of bank-specific control variables (lagged growth rate of the risk-weighted assets, squared values of the ratios, regulatory ratios not included in the pairwise interaction, size, share of loan business, NPL ratio); α is the intercept, σ_i denotes bank fixed effects, η_t time fixed effects and ϵ the vector of error terms, with i referring to bank i and t to time t. β_1, β_2, β_3, λ and γ are vectors of coefficients to be estimated.

In this equation, our variable of interest is β_1, the coefficient of the interaction term between two regulatory ratios. The sign of this coefficient can help to shed light on the substitutability and complementarity between regulatory ratios as well as the dampening or amplifying effects. Indeed, in the above specification, β_1 can be seen as the cross-derivative of $\Delta L_{i,t}$ with respect to Reg_1 and Reg_2, i.e.:

$$\beta_1 = \frac{\partial^2 \Delta L_{i,t}}{\partial Reg_1 \partial Reg_2} \tag{34}$$

By analogy with the definition of (strategic) complementarity (substitutability) used in the game theory and theory of firm,[3] one could interpret the sign of β_1 as follows:

- if β_1 has the same sign as β_2 and β_3: the two regulatory ratios are complements from the perspective of their impact on banks' lending growth (or have an amplifying effect)
- if β_1 has the opposite sign compared to β_2 and β_3: the two regulatory ratios are substitutes from the perspective of their impact on banks' lending growth (or have a dampening effect)

Based on this interpretation, the interaction between two regulatory ratios has a dampening (amplifying) effect on lending if the absolute value of the total effects on lending is lower (larger) than the sum of the individual effects of each ratio taken separately.

4.3 Results

4.3.1 Baseline estimation

This section presents the results of our baseline estimation of the lending growth rate, using the risk-based Tier 1 capital management buffer (MB) and the actual levels of the other regulatory ratios.[4] The risk-based capital management buffer might be considered as a better indicator than the actual risk-based capital ratio as it reflects the amount of capital available that can be used to finance loan growth. Table 5 displays the results associated with each pairwise interaction. Columns 1 to 3 of Table 5 present the results associated with the full sample, while columns 4 to 9 those associated with the restricted sample of the six largest banks including the NSFR analysis. Overall, the degree of interaction between the different ratios is relatively weak as only one pairwise interaction shows up with a significant effet on lending growth: the one between the management buffer and the LCR in the full sample (column 2). The opposite signs between the coefficient on the interaction terms (0.02), on the one hand, and the coefficients on the individual ratios, on the

[3]In the firm theory, inputs x and y are complements if the firm's production function if the marginal product of x is increasing in quantity of y. Inputs x and y are substitutes if the marginal product of x is decreasing in quantity of y.

[4]Overall risk-based capital requirements include Pillar 1, Pillar 2 and the combined buffer requirement (capital conservation buffer, global and other systemically important institution buffers, systemic risk buffers and counter-cyclical buffer). These requirements are either common or specific to the bank. For the other ratios (leverage, LCR and NSFR), the regulatory minimum is time- and bank-invariant.

other hand, suggest that the two ratios act as partial substitutes with regard to their effects on lending growth. Indeed, the compounded effect of the two ratios is lower than the sum of their individual effects. When the interaction term between the the management buffer and the LCR increases by 1 percentage point, this interaction is associated with a reduction in the negative compounded effect of the two ratios on lending growth by 0.02 percentage point or 2 basis point.

However, the negative sign on the management buffer and the LCR variables (-1.97 and -0.29, respectively, column 2) comes as a surprise. This suggests that the larger the capital management buffer and the higher the LCR, the lower the lending growth. This stands in contrast with most literature findings. This result can be explained by the fact that on average, the regulatory ratios are not really binding over the period of observation. In this case, lending growth is not primarily determined by the change in the regulatory ratios, but by market share and profit objectives, leading banks to take on more risks in good times. The lagged growth rate of the risk-weighted assets is not found to significantly impact lending growth. In order to analyse this puzzling finding further, the next subsections focus on the impact of the regulatory interactions under different variants: the focus on weaker banks and on periods of high financial stress.

Table 5: Baseline estimation of yoy lending growth (loans to non-financial private sector)- Use of the risk-based Tier 1 capital management buffer and other ratios- Whole period

	Full sample- without NSFR			**Sample of 6 largest banks - with NSFR**					
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
MB*Leverage	0.03			-0.56					
	(0.10)			(0.40)					
MB*LCR		0.02**			-0.01				
		(0.01)			(0.01)				
Leverage*LCR			0.02			0.17			
			(0.01)			(0.09)			
MB*NSFR							-0.02		
							(0.03)		
Leverage*NSFR								0.52	
								(0.33)	
LCR*NSFR									-0.00
									(0.02)
MB	0.32	-1.97**	-0.06	1.14	1.00	-1.05**	2.11	-0.29	-0.46
	(0.64)	(0.91)	(0.22)	(1.33)	(1.91)	(0.38)	(3.35)	(0.61)	(0.86)
Leverage	-1.24	-0.30	-3.32	5.11	1.62	-23.02	1.52	-56.38	1.74
	(1.55)	(0.79)	(2.03)	(3.00)	(1.43)	(14.17)	(1.56)	(40.43)	(2.16)
LCR	-0.02	-0.29**	-0.15	0.01	0.12	-0.79*	0.01		
	(0.01)	(0.13)	(0.12)	(0.02)	(0.22)	(0.35)	(0.02)		
NSFR				-0.72***	-0.75***	-0.71***	-0.46	-1.70	1.16
				(0.17)	(0.14)	(0.17)	(1.74)	(1.42)	(2.90)
$MB^2*Leverage^2$	-0.00			0.00					
	(0.00)			(0.00)					
MB^2*LCR^2		-0.00**			0.00				
		(0.00)			(0.00)				
$Leverage^2*LCR^2$			-0.00			-0.00*			
			(0.00)			(0.00)			
MB^2*NSFR^2							0.00		
							(0.00)		
$Leverage^2*NSFR^2$								-0.00	
								(0.00)	
LCR^2*NSFR^2									0.00
									(0.00)
MB^2	-0.02	0.02		0.02	-0.04		-0.09	2.38	
	(0.02)	(0.02)		(0.03)	(0.04)		(0.12)	(1.69)	
$Leverage^2$	0.05		0.12*	-0.04		1.33		0.02	0.43
	(0.10)		(0.07)	(0.12)		(0.77)		(0.02)	(2.28)
LCR^2		0.00	0.00		-0.00	0.00**			-0.00
		(0.00)	(0.00)		(0.00)	(0.00)			(0.00)
$NSFR^2$							-0.00	-0.00	-0.01
							(0.01)	(0.01)	(0.01)
RWA (% chge)	-0.03	-0.04	-0.01	-0.06	-0.01	-0.10	-0.04	-0.04	-0.04
	(0.07)	(0.07)	(0.06)	(0.12)	(0.11)	(0.10)	(0.14)	(0.11)	(0.11)
Δv2x	-0.11	0.11	-0.47	0.52	0.95	-2.47	0.66	0.57	0.51
	(1.48)	(1.59)	(1.41)	(2.06)	(2.89)	(2.66)	(2.40)	(2.34)	(2.69)
Δgdp	-29.67	-21.53	-37.32	-31.11	-4.08	-99.62	-16.63	-37.22	-17.91
	(56.45)	(56.55)	(51.67)	(69.74)	(85.76)	(90.66)	(62.75)	(69.96)	(57.93)
Δinflation	164.35	149.52	180.43	281.81	187.10	461.99	219.82	299.05	222.71
	(202.32)	(195.34)	(183.61)	(274.68)	(283.74)	(341.20)	(223.04)	(274.13)	(213.26)
ΔEuribor	-31.42	-35.42	-18.40	-83.51	-66.73	14.11	-67.39	-92.77	-60.94
	(41.43)	(41.63)	(40.19)	(68.27)	(80.76)	(48.83)	(94.98)	(81.44)	(109.59)
Size (i, t-4)	-3.20**	-3.09**	-3.36**	-4.55**	-4.09***	-4.27***	-4.20***	-4.61***	-4.07***
	(1.52)	(1.33)	(1.45)	(1.27)	(0.73)	(0.53)	(0.74)	(0.51)	(0.56)
Loan share (i, t-4)	-0.65**	-0.66**	-0.66**	-1.92**	-1.74**	-1.91**	-1.84***	-1.78**	-1.74**
	(0.26)	(0.27)	(0.26)	(0.52)	(0.55)	(0.52)	(0.45)	(0.50)	(0.51)
ΔNPL (i, t-4)	-0.73**	-0.82***	-0.77**	-2.07**	-2.18**	-2.26**	-2.35***	-2.11**	-1.88**
	(0.34)	(0.28)	(0.32)	(0.55)	(0.57)	(0.73)	(0.55)	(0.70)	(0.50)
Constant	66.77***	73.66***	61.31***	181.74***	183.16***	266.48***	174.70	321.68*	70.53
	(21.07)	(20.19)	(22.14)	(35.03)	(31.21)	(35.17)	(105.05)	(129.61)	(220.87)
Bank Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	511	511	511	108	108	108	108	108	108
R-squared	0.19	0.21	0.18	0.68	0.68	0.68	0.68	0.68	0.67
Number of banks	54	54	54	6	6	6	6	6	6

Sources: ACPR, Authors' calculations.
Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

4.3.2 Robustness checks

We then carried out several robustness checks. We first tried to partition our banking sample based on the value of the bank's average risk weight, in line with the predictions of our theoretical model concerning the impact of the threshold value of θ_L. Therefore, we introduced a dummy variable identifying banks exhibiting an average risk weight higher than 50 percent or 62.5 percent and interacted it with the Tier1 risk-based capital ratio and the leverage ratio. However, the estimation of the model corresponding to Equation (35) with this new specification provides insignificant coefficients on the interaction terms involving this risk weight dummy variable, while the coefficients on the variables not interacted with this dummy are very similar compared to the baseline estimation (results not presented but available upon request). This finding reflects the fact that the baseline results are determined by the banks exhibiting an average risk weight lower than 50 percent or 62.5 percent. Indeed, the other banks, i.e. those exhibiting an average risk above the threshold value of 62.5 percent, make up a very small minority of our sample (around 10 percent of the observations at the last period of estimation, for example) and have thus no significant impact on the overall results.

Next, we want to shed light on the effects of interactions between regulatory ratios for the lending growth of banks with weaker regulatory ratios as the latter are supposed to be more constrained by regulatory ratios because their ratios are closer to the regulatory minima. Banks with weaker regulatory ratios are identified as banks displaying capital or liquidity ratios below the 25th percentile of the distribution by date. A dummy variable equal to 1 is associated to these banks and is interacted with each of the regulatory ratio. Results are displayed in Table 6 and differ little from the previous ones. With this specification, one pairwise interaction shows up with a (weakly) significant effect on lending growth: the one between the leverage ratio and the NSFR in the restricted sample (column 8), with a coefficient on the interaction term of -0.18. These results show a kind of specificity of the behaviour of the banks with weaker regulatory ratios but do not indicate that these banks drive the overall results of the effects of the interactions between regulatory ratios on lending growth.

Table 6: Estimation of yoy lending growth - Banks with weaker regulatory ratios

	Full sample- without NSFR			Sample of 6 largest banks - with NSFR					
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
MB*Leverage*d_low_MB	0.20			0.30					
	(0.16)			(0.37)					
MB*LCR*d_low_MB		0.01			0.01				
		(0.01)			(0.01)				
Leverage*LCR*d_low_Leverage			-0.01			-0.04			
			(0.02)			(0.03)			
MB*NSFR*d_low_MB							0.01		
							(0.02)		
Leverage*NSFR*d_low_Leverage								-0.18*	
								(0.07)	
LCR*NSFR*d_low_LCR									-0.00
									(0.01)
d_low_MB	-5.81*	-2.00		-0.71	-1.19		-3.62		
	(3.01)	(2.80)		(3.29)	(2.67)		(4.18)		
d_low_Leverage	14.02**		13.02**	3.15		20.92		61.79**	
	(6.40)		(6.46)	(14.30)		(12.51)		(22.09)	
d_low_LCR		12.90**	5.61		3.52	3.36			-42.80**
		(5.74)	(5.24)		(12.53)	(12.21)			(15.96)
d_low_NSFR							10.68	-5.30	-2.30
							(17.96)	(15.26)	(9.72)
MB*d_low_MB	-0.13	-0.37		-0.91	-0.40		-0.49		
	(0.30)	(0.56)		(1.01)	(0.45)		(1.31)		
Leverage*d_low_Leverage	-2.63**		-1.84	-0.76		-0.81		-0.15	
	(1.24)		(2.20)	(2.66)		(0.93)		(2.29)	
LCR*d_low_LCR		-0.10**	-0.04		-0.02	-0.01			0.62
		(0.05)	(0.04)		(0.10)	(0.10)			(0.38)
NSFR*d_low_NSFR							-0.09	0.07	0.03
							(0.18)	(0.15)	(0.10)
MB*Leverage	0.11			-0.50					
	(0.09)			(0.36)					
MB*LCR		0.01***			0.00				
		(0.00)			(0.01)				
Leverage*LCR			0.01			0.05			
			(0.01)			(0.04)			
MB*NSFR							0.01		
							(0.01)		
Leverage*NSFR								0.17	
								(0.12)	
LCR*NSFR									-0.00
									(0.00)
MB	-0.68	-1.38***	-0.05	1.25	-1.06	-1.09**	-2.39**	-1.31**	-0.92
	(0.50)	(0.50)	(0.26)	(1.40)	(0.73)	(0.37)	(0.81)	(0.35)	(0.60)
Leverage	-0.49	-0.25	-0.55	4.16	1.91	2.87	2.11	2.64	2.75
	(1.22)	(0.77)	(1.10)	(2.28)	(1.52)	(3.57)	(2.00)	(11.18)	(1.38)
LCR	-0.01	-0.10***	-0.05	0.01	-0.01	0.00	-0.00	0.01	0.20
	(0.01)	(0.04)	(0.08)	(0.02)	(0.02)	(0.10)	(0.02)	(0.02)	(0.33)
NSFR				-0.66**	-0.63***	-0.65***	-0.63**	-0.65	-0.24
				(0.19)	(0.15)	(0.15)	(0.16)	(0.60)	(0.41)
RWA (% chge)	-0.03	-0.05	-0.01	-0.06	-0.04	-0.08	-0.12	-0.13	-0.09
	(0.07)	(0.07)	(0.06)	(0.15)	(0.11)	(0.10)	(0.15)	(0.08)	(0.09)
Constant	48.49***	54.85***	42.55**	177.78***	177.29***	143.75**	173.89***	108.56	122.15*
	(15.58)	(14.47)	(16.66)	(43.18)	(38.42)	(43.38)	(40.08)	(65.62)	(52.35)
Macro controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Squared terms	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank-specific controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	511	511	511	108	108	108	108	108	108
R-squared	0.20	0.22	0.19	0.69	0.69	0.69	0.69	0.69	0.71
Number of banks	54	54	54	6	6	6	6	6	6

Sources: ACPR, Authors' calculations.
Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

We also focused on periods of financial stress during which regulatory ratios are supposed to be more binding as they are usually associated with higher risk aversion. These periods correspond to values of the V2X index above the 75th percentile of the distribution (i.e. a value of 26.8 when taking the whole period of observation). Therefore, we introduced interaction terms between pairwise regulatory ratios and a dummy variable equal to 1 when the current value of the V2X index exceeded this threshold value. The results displayed in Table 7 provide interesting new insights. In such periods, three pairwise interactions have a significant effect on lending growth, all in the full sample: the one between the risk-based Tier 1 capital management buffer and the leverage ratio (column 1), the one between the risk-based Tier 1 capital management buffer and the LCR (column 2) and the one between the leverage ratio and the LCR (column 3). The opposite signs between the coefficient on the interaction term and the coefficients on the individual ratios indicate a substitutability relationship. However, the specification involving the interaction between the leverage ratio and the LCR in the full sample (column 3) is the only one displaying all the expected signs. With this specification, the individual leverage ratio and LCR have an expected positive, albeit not statistically significant, effect on lending growth: the higher these two ratios in periods of high V2X, the higher the lending growth, in contrast with the baseline estimation. This result indicates that the two ratios act as partial substitutes with regard to their effects on lending growth. Indeed, the compounded effect of the two ratios is lower than the sum of their individual effects. When the leverage ratio and the LCR increase in periods of financial stress, there is a positive effect on lending growth. However, if their interaction term increases by 1 percentage point, this interaction is associated with a reduction in their positive compounded effect on lending growth by 0.06 percentage points or 6 basis points. This suggests a potential dampening effect of the interaction on lending growth.

Overall, these results indicate that regulatory ratios interact more in periods of financial instability. They seem to act as partial substitutes with regard to their effects on lending growth.

Table 7: Estimation of yoy lending growth - Periods of high V2X

	Full sample- without NSFR			Sample of 6 largest banks - with NSFR					
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
MB*Leverage*d_high_V2X	0.64***			-10.92					
	(0.15)			(6.61)					
MB*LCR*d_high_V2X		0.05***			0.35				
		(0.02)			(0.25)				
Leverage*LCR*d_high_V2X			-0.06*			1.65			
			(0.03)			(0.94)			
MB*NSFR*d_high_V2X							-0.76		
							(0.43)		
Leverage*NSFR*d_high_V2X								0.42	
								(2.89)	
LCR*NSFR*d_high_V2X									-0.09
									(0.11)
d_high_V2X	28.38	48.08	-26.13	-29.80	-244.28*	516.97	-572.44	92.39	-832.85
	(21.11)	(36.50)	(38.09)	(39.55)	(107.26)	(375.40)	(493.76)	(837.29)	(1,228.26)
MB*d_high_V2X	-2.59**	-7.44***		37.36	-51.31		78.19		
	(1.10)	(2.76)		(22.04)	(36.02)		(44.57)		
Leverage*d_high_V2X	-5.45***		7.54	-13.22		-241.26		-48.32	
	(1.82)		(4.55)	(29.14)		(133.65)		(310.61)	
LCR*d_high_V2X		-0.32	0.41		3.72**	-3.15			11.98
		(0.22)	(0.30)		(1.32)	(3.41)			(12.15)
NSFR*d_high_V2X							9.26	-0.28	6.36
							(8.11)	(9.85)	(14.20)
MB*Leverage	-0.10			-0.87					
	(0.10)			(0.48)					
MB*LCR		0.01**			0.00				
		(0.00)			(0.00)				
Leverage*LCR			0.01			-0.02			
			(0.01)			(0.04)			
MB*NSFR							0.01		
							(0.01)		
Leverage*NSFR								0.00	
								(0.12)	
LCR*NSFR									-0.00
									(0.00)
MB	0.45	-0.86**	-0.03	2.73	-0.79	-0.78*	-1.25	-0.55	-0.73
	(0.51)	(0.43)	(0.23)	(1.75)	(0.58)	(0.34)	(0.85)	(0.43)	(0.60)
Leverage	1.12	-0.07	-0.94	6.32*	1.40	6.78	1.48	6.43	1.83
	(1.00)	(0.77)	(1.21)	(2.90)	(1.47)	(5.43)	(1.73)	(13.06)	(1.77)
LCR	-0.01	-0.07**	-0.06	0.00	-0.02	0.13	0.02	0.02	0.17
	(0.01)	(0.03)	(0.05)	(0.03)	(0.04)	(0.15)	(0.02)	(0.02)	(0.37)
NSFR				-0.71***	-0.93***	-1.00***	-0.87***	-0.70	-0.59
				(0.10)	(0.16)	(0.17)	(0.18)	(0.59)	(0.51)
RWA (% chge)	-0.02	-0.07	-0.02	-0.05	-0.00	-0.03	-0.04	-0.07	-0.04
	(0.06)	(0.06)	(0.06)	(0.14)	(0.13)	(0.13)	(0.13)	(0.13)	(0.12)
Constant	32.25**	46.95***	43.32**	169.07***	214.58***	190.15***	198.57***	150.19*	180.52**
	(15.49)	(14.38)	(16.83)	(27.74)	(38.57)	(29.99)	(34.22)	(66.04)	(54.55)
Macro controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Squared terms	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank-specific controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	511	511	511	108	108	108	108	108	108
R-squared	0.24	0.23	0.20	0.74	0.74	0.74	0.71	0.70	0.69
Number of banks	54	54	54	6	6	6	6	6	6

Sources: ACPR, Authors' calculations.
Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Finally, we interacted dummies identifying weaker banks and periods of financial stress to assess the lending behaviour of weakers banks in periods of financial stress. Results are presented in Table 8. In this specification, two pairwise interactions show up with a significant effect on the growth rate of loans to households and non-financial corporations, both in the full sample: the interaction between the risk-based Tier 1 capital management buffer and the leverage ratio (column 1), and the one between the risk-based Tier 1 capital management buffer and the LCR (column 2). In both specifications, the risk-based Tier1 capital management buffer has a significantly positive effect on lending growth, as expected, when we focus on less capitalised banks in periods of high stress, reflecting more binding regulatory constraints for such banks in such periods. The significantly negative sign on the interaction term in both specifications (-0.58 and -0.04, respectively, in columns 1 and 2) suggests a substitutability relationship between the risk-based Tier 1 capital management buffer on the one hand, the leverage ratio and the LCR on the other hand, with the positive effect of the individual risk-based Tier 1 capital management buffer reduced by negative coefficients on the interaction terms.

Overall, these results confirm that regulatory ratios seem to interact more and to act as partial substitutes with regard to their effects on lending growth for weaker banks in periods of high stress.

Table 8: Estimation of yoy lending growth - Focus on weaker banks in periods of high V2X

	Full sample- without NSFR			**Sample of 6 largest banks - with NSFR**					
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
MB*Leverage*d_low_MB*d_high_V2X	-0.58***			-1.01					
	(0.12)			(0.62)					
MB*LCR*d_low_MB*d_high_V2X		-0.04***			0.02				
		(0.01)			(0.01)				
Leverage*LCR*d_low_Lev*d_high_V2X			-0.01			0.02			
			(0.01)			(0.01)			
MB*NSFR*d_low_MB*d_high_V2X							-0.05		
							(0.04)		
Leverage*NSFR*d_low_Lev*d_high_V2X								-0.03	
								(0.03)	
LCR*NSFR*d_low_LCR*d_high_V2X									-0.00
									(0.01)
MB*d_low_MB*d_high_V2X	3.22***	5.57***		5.03	-2.15		6.01		
	(0.83)	(1.62)		(3.35)	(1.85)		(4.43)		
Leverage*d_low_Lev*d_high_V2X	0.05		1.83	0.32		-1.89		3.83	
	(0.26)		(1.12)	(0.19)		(1.84)		(3.66)	
LCR*d_low_LCR*d_high_V2X		-0.01	0.00		0.00	0.01			0.13
		(0.01)	(0.01)		(0.02)	(0.01)			(0.95)
NSFR*d_low_NSFR*d_high_V2X							-0.03	-0.03	-0.02
							(0.02)	(0.03)	(0.02)
d_high_V2X	-4.59	11.09	6.32	9.29	-7.19	30.50	31.43	51.93	44.19
	(23.38)	(24.20)	(23.63)	(47.16)	(44.51)	(45.23)	(53.38)	(52.63)	(39.35)
d_low_MB	-1.21	-1.37		3.39	0.10		-0.54		
	(1.26)	(1.52)		(2.45)	(2.51)		(2.63)		
d_low_Leverage	0.73		2.27	-0.15		-1.40		-0.52	
	(1.33)		(1.93)	(0.56)		(1.87)		(4.60)	
d_low_LCR		0.86	0.72		1.37	1.44			3.53
		(0.63)	(0.58)		(0.86)	(1.11)			(3.78)
d_low_NSFR							1.71**	1.82	1.51
							(0.58)	(0.92)	(0.92)
MB	0.11	-0.09	0.03	-0.16	-0.84	-1.00*	-1.23**	-0.96	-0.75
	(0.27)	(0.30)	(0.26)	(0.57)	(0.46)	(0.42)	(0.45)	(0.49)	(0.56)
Leverage	0.23	-0.01	0.04	3.30	2.00	4.33	1.92	5.12	2.30
	(0.82)	(0.73)	(0.93)	(2.44)	(1.81)	(2.25)	(2.14)	(5.17)	(1.59)
LCR	-0.02	-0.01	-0.01	0.02	0.00	0.06	0.01	0.01	0.10**
	(0.01)	(0.02)	(0.02)	(0.02)	(0.02)	(0.06)	(0.02)	(0.02)	(0.03)
NSFR				-0.72***	-0.73***	-0.76***	-0.67***	-0.48	-0.36*
				(0.13)	(0.13)	(0.11)	(0.13)	(0.28)	(0.14)
RWA (% chge)	-0.01	-0.03	-0.02	-0.03	-0.03	-0.09	-0.08	-0.12	-0.08
	(0.06)	(0.07)	(0.06)	(0.15)	(0.12)	(0.12)	(0.13)	(0.10)	(0.11)
Constant	37.09**	38.72***	39.74**	171.18***	183.65***	166.70***	178.75***	142.85**	138.22**
	(14.85)	(13.68)	(16.45)	(25.67)	(38.47)	(39.52)	(35.59)	(43.14)	(38.94)
Macro controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Squared terms	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank-specific controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	511	511	511	108	108	108	108	108	108
R-squared	0.24	0.20	0.18	0.70	0.69	0.69	0.70	0.70	0.70
Number of banks	54	54	54	6	6	6	6	6	6

Sources: ACPR, Authors' calculations.
Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

5 Conclusion

This paper examined the expected impact of adding liquidity rules to capital rules in the Basel III regulatory environment on the financing of the economy. Using the results of a theoretical model, we show under which conditions some regulatory ratios may bind while others may not. We also show that determining the optimal level of loans resulting from the imposition of multiple constraints is not straightforward and may depend on the combination of the parameters of various regulatory ratios. The empirical model estimating year-on-year lending growth of a panel of 120 French banks since 2014 indicates that three pairwise interactions, most of them involving the risk-based Tier 1 capital management buffer, have a significant effect on lending growth. More specifically, our results highlight a significant and partial level of substitutability between the risk-based Tier 1 capital management buffer and the LCR over the entire period. We also emphasize the specificity of the lending behaviour of banks with lower regulatory ratios and the changes observed in periods of financial stress. Our results show that the risk-based Tier 1 capital management buffer interacts more with the other ratios, in particular the leverage ratio and the LCR, during such periods and for weaker banks, with the positive individual effect of regulatory ratios on lending growth partly reduced by the effect of their interactions.

There are still important uncovered issues which need to be addressed. Considering the behaviour of the different stakeholders at play and corporate governance mechanisms is an important aspect. Introducing such a dual capital-liquidity constraint in a general equilibrium model of banking activities is another important way to assess the impact of such combined rules on the economy as a whole and on financial stability. The implications of the NSFR on the incentives created for banks to borrow from non-banking financial intermediaries (NBFI) on a long-term basis, while NBFI are funded on a short-term basis, would thus be worth analyzing, once the NSFR series are long enough. Also, whether these new rules have effectively improved the resiliency of banks to shocks is still an open question as their relatively good performance during the Covid-19 pandemic is presumably, to a large extent, explained by massive public support to the economy.

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A Annexes

A.1 Proof of the results of the theoretical model

Given that we have three variables of choice and three constraints, we can solve the optimisation programme and find the solutions and optimal values of L or S. According to Kuhn and Tucker's conditions, the first-order conditions of the Lagrangian function (15) are the following:

$$\begin{aligned}\frac{\partial \mathcal{L}}{\partial S} &= \tilde{r^s} - \tilde{r^k} - \rho(\sigma^2_{\tilde{r^s}} S + \sigma_{\tilde{r^d}\tilde{r^s}} D + \sigma_{\tilde{r^s}\tilde{r^l}} L + \sigma_{\tilde{r^s}\tilde{r^b}} B) \\ &\quad + \lambda_1 \phi + \lambda_2(1 - \overline{NSFR}.rsf_S) + \lambda_3(1 - \overline{LR}) = 0 \end{aligned} \tag{35}$$

$$\begin{aligned}\frac{\partial \mathcal{L}}{\partial L} &= \tilde{r^l} - \tilde{r^k} - \rho(\sigma^2_{\tilde{r^l}} L + \sigma_{\tilde{r^s}\tilde{r^l}} S + \sigma_{\tilde{r^l}\tilde{r^b}} B + \sigma_{\tilde{r^d}\tilde{r^l}} D) \\ &\quad + \lambda_2(1 - \overline{NSFR}.rsf_L) + \lambda_3(1 - \overline{LR}) = 0 \end{aligned} \tag{36}$$

$$\begin{aligned}\frac{\partial \mathcal{L}}{\partial D} &= \tilde{r^k} - \tilde{r^d} - \rho(\sigma^2_{\tilde{r^d}} D + \sigma_{\tilde{r^d}\tilde{r^l}} L + \sigma_{\tilde{r^d}\tilde{r^s}} S + \sigma_{\tilde{r^d}\tilde{r^b}} B) \\ &\quad - \lambda_1 \overline{LCR}.l_D - \lambda_2(1 - asf_D) - \lambda_3 = 0 \end{aligned} \tag{37}$$

The other first-order conditions are the following:

$$\frac{\partial \mathcal{L}}{\partial \lambda_1} = \phi S - \overline{LCR}(l_D D + l_B B) \geq 0 \tag{38}$$

$$\frac{\partial \mathcal{L}}{\partial \lambda_2} = S + L - D - B + -asf_D D + asf_B B - \overline{NSFR}(rsf_S S + rsf_L L) \geq 0 \tag{39}$$

$$\frac{\partial \mathcal{L}}{\partial \lambda_3} = S + L - D - B - \overline{LR}(S + L) \geq 0 \tag{40}$$

Using equation (37), we show that the value of λ_1 is higher when we drop the NSFR constraint compared to the case when we introduce the three constraints. Indeed, the difference is equal to: $-\lambda_2(1 - asf_D)$ which is by definition negative as $\lambda_2 \geq 0$ and $1 - asf_D > 0$. The same observation can be made as regards the relationship between λ_1 and λ_3: the value of λ_1 diminishes when we introduce λ_3.

Therefore, this provides a piece of evidence that the constraints interact with each other as the introduction of the NSFR for example reduces the degree of tightness of the LCR ratio constraint, meaning that it helps the bank to fulfill its other liquidity requirement.

We can finally solve the optimisation programme and get the optimal values of L, S and D.

After diverse substitutions, we get the following value of L^*.

$$
\begin{aligned}
L^* \quad = \quad & K^*[\frac{1}{\theta_L.\gamma\overline{K}} - \frac{\theta_S}{\theta_L}\frac{\overline{LCR}.l_D}{\phi}(\frac{(\overline{LR} - \overline{NSFR}.rsf_L)\frac{\theta_S}{\theta_L}\frac{\overline{LCR}.l_B}{\phi} - asf_B - \frac{\overline{LCR}.l_B}{\phi}(\overline{LR} - \overline{NSFR}.rsf_S)}{asf_D + \frac{\overline{LCR}.l_D}{\phi}(\overline{LR} - \overline{NSFR}.rsf_S) - (\overline{LR} - \overline{NSFR}.rsf_L)\frac{\theta_S}{\theta_L}\frac{\overline{LCR}.l_D}{\phi}} \\
& \times \frac{1 + ((1 - \frac{\theta_S}{\theta_L})\frac{\overline{LCR}.l_D}{\phi} - 1)\frac{Q}{\theta_L.\gamma\overline{K}} - \frac{1}{\theta_L.\gamma\overline{K}}}{(\frac{\overline{LCR}.}{\phi}(\overline{LCR}.l_D - \frac{\theta_S}{\theta_L}l_D + l_B) - 1).P - \frac{\theta_S}{\theta_L}\frac{\overline{LCR}.l_B}{\phi} - 1} \\
& - \frac{\overline{LR} - \overline{NSFR}.rsf_L}{\theta_L.\gamma\overline{K}(asf_D + \frac{\overline{LCR}.l_D}{\phi}(\overline{LR} - \overline{NSFR}.rsf_S) - (\overline{LR} - \overline{NSFR}.rsf_L)\frac{\theta_S}{\theta_L}\frac{\overline{LCR}.l_D}{\phi}}) \\
& - \frac{\theta_S}{\theta_L} \times \frac{\overline{LCR}.l_B}{\phi} \times \frac{1 + ((1 - \frac{\theta_S}{\theta_L})\frac{\overline{LCR}.l_D}{\phi} - 1)\frac{Q}{\theta_L.\gamma\overline{K}} - \frac{1}{\theta_L.\gamma\overline{K}}}{(\frac{\overline{LCR}}{\phi}(l_D - \frac{\theta_S}{\theta_L}l_D + l_B) - 1).P - \frac{\theta_S}{\theta_L}\frac{\overline{LCR}.l_B}{\phi} - 1}]
\end{aligned}
\tag{41}
$$

with:

$$
P = \frac{(\overline{LR} - \overline{NSFR}.rsf_L)\frac{\theta_S}{\theta_L}\frac{\overline{LCR}.l_B}{\phi} - asf_B - \frac{\overline{LCR}.l_B}{\phi}(\overline{LR} - \overline{NSFR}.rsf_S)}{asf_D + \frac{\overline{LCR}.l_D}{\phi}(\overline{LR} - \overline{NSFR}.rsf_S) - (\overline{LR} - \overline{NSFR}.rsf_L)\frac{\theta_S}{\theta_L}\frac{\overline{LCR}.l_D}{\phi}} \tag{42}
$$

and

$$
Q = \frac{\overline{LR} - \overline{NSFR}.rsf_L}{asf_D + \frac{\overline{LCR}.l_D}{\phi}(\overline{LR} - \overline{NSFR}.rsf_S) - (\overline{LR} - \overline{NSFR}.rsf_L)\frac{\theta_S}{\theta_L}\frac{\overline{LCR}.l_D}{\phi}} \tag{43}
$$

Therefore, we get a non-nil solution for L, as well as for S, D and B, that only depends on exogenous parameters (regulatory thresholds and weights, as well as current ratios) and on the bank's capital target. This equation can be tested in the empirical strategy in the last section of the paper with the follwing form:.

$$
L_t = \beta\Gamma\gamma\overline{K}RWA_{t-1} + (1 - \beta)\Gamma K_{t-1} + controls + \epsilon_t \tag{44}
$$

where Γ is a constant expressed as:

$$
\begin{aligned}
\Gamma \quad = \quad & \frac{1}{\theta_L.\gamma\overline{K}} - \frac{\theta_S}{\theta_L}\frac{\overline{LCR}.l_D}{\phi}(\frac{(\overline{LR} - \overline{NSFR}.rsf_L)\frac{\theta_S}{\theta_L}\frac{\overline{LCR}.l_B}{\phi} - asf_B - \frac{\overline{LCR}.l_B}{\phi}(\overline{LR} - \overline{NSFR}.rsf_S)}{asf_D + \frac{\overline{LCR}.l_D}{\phi}(\overline{LR} - \overline{NSFR}.rsf_S) - (\overline{LR} - \overline{NSFR}.rsf_L)\frac{\theta_S}{\theta_L}\frac{\overline{LCR}.l_D}{\phi}} \\
& \times \frac{1 + ((1 - \frac{\theta_S}{\theta_L})\frac{\overline{LCR}.l_D}{\phi} - 1)\frac{Q}{\theta_L.\gamma\overline{K}} - \frac{1}{\theta_L.\gamma\overline{K}}}{(\frac{\overline{LCR}.}{\phi}(l_D - \frac{\theta_S}{\theta_L}l_D + l_B) - 1).P - \frac{\theta_S}{\theta_L}\frac{\overline{LCR}.l_B}{\phi} - 1} \\
& - \frac{\overline{LR} - \overline{NSFR}.rsf_L}{\theta_L.\gamma\overline{K}(asf_D + \frac{\overline{LCR}.l_D}{\phi}(\overline{LR} - \overline{NSFR}.rsf_S) - (\overline{LR} - \overline{NSFR}.rsf_L)\frac{\theta_S}{\theta_L}\frac{\overline{LCR}.l_D}{\phi}}) \\
& - \frac{\theta_S}{\theta_L} \times \frac{\overline{LCR}.l_B}{\phi} \times \frac{1 + ((1 - \frac{\theta_S}{\theta_L})\frac{\overline{LCR}.l_D}{\phi} - 1)\frac{Q}{\theta_L.\gamma\overline{K}} - \frac{1}{\theta_L.\gamma\overline{K}}}{(\frac{\overline{LCR}.}{\phi}(l_D - \frac{\theta_S}{\theta_L}l_D + l_B) - 1).P - \frac{\theta_S}{\theta_L}\frac{\overline{LCR}.l_B}{\phi} - 1}
\end{aligned}
\tag{45}
$$

and β and γ are parameters to be estimated.

We can also replace the amount of capital with the management buffer $\gamma\overline{K}$ in Equation (44):

$$
L_t = (\beta\gamma + (1 - \beta)(1 + \gamma))\Gamma\overline{K}RWA_{t-1} + controls + \epsilon_t \tag{46}
$$

We finally can express the growth rate of L_t which will be estimated in our empirical model as:

$$
\dot{L_t} = (\beta\gamma + (1 - \beta)(1 + \gamma))\Gamma RW\dot{A}_{t-1} + controls + \epsilon_t \tag{47}
$$