Special Features

A The impact of the Basel III leverage ratio on risk-taking and bank stability[1]

The Basel III leverage ratio aims to constrain the build-up of excessive leverage in the banking system and to enhance bank stability. Concern has been raised, however, that the non-risk-based nature of the leverage ratio could incentivise banks to increase their risk-taking. This special feature presents theoretical considerations and empirical evidence for EU banks that a leverage ratio requirement should only lead to limited additional risk-taking relative to the induced benefits of increasing loss-absorbing capacity, thus resulting in more stable banks.

Introduction

As a response to the global financial crisis, the Basel Committee on Banking Supervision (BCBS) decided to undertake a major reform of the regulatory framework of the banking system. Under the new Basel III banking regulations, a non-risk-based leverage ratio (LR) requirement will be introduced alongside the risk-based capital framework with the aim to "restrict the build-up of excessive leverage in the banking sector to avoid destabilising deleveraging processes that can damage the broader financial system and the economy".[2] However, this move away from a solely risk-based capital requirement has raised some concern about possible increased bank risk-taking potentially offsetting the benefits gained from requiring banks bound by the LR to hold more capital.

This special feature addresses precisely this trade-off between additional loss-absorbing capacity and higher bank risk-taking associated with an LR requirement in both a theoretical and empirical setting. Using a simple theoretical model, it is shown that the increased incentive to take risk is more than outweighed by the increase in loss-absorbing capacity from higher capital, thus leading to more stable banks. These results are confirmed within an empirical analysis on a large sample of EU banks. The empirical estimates suggest that banks bound by the LR increase their risk-weighted assets to total assets ratio by around 1.5-2 percentage points more than they otherwise would, i.e. without an LR requirement. Importantly, this small increase in risk-taking is more than compensated for by the substantial increase in capital positions for highly leveraged banks, which results in significantly lower estimated distress probabilities for banks bound by the LR.

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[1] This special feature was prepared by Michael Grill, Jan Hannes Lang and Jonathan Smith. The exposition is based on the analysis in Grill, M., Lang, J.H. and Smith, J. (2015), *The Leverage Ratio, Risk-Taking and Bank Stability*, mimeo (See EBA 4th Annual Research Workshop Website).

[2] See the BCBS press release of 12 January 2014 on BCBS (2014a), *Basel III leverage ratio framework and disclosure requirements*, January (available at http://www.bis.org/publ/bcbs270.htm). The Basel III regulations also include a strengthened risk-based capital framework and two new liquidity requirements, the Liquidity Coverage Ratio (LCR) and the Net Stable Funding Ratio (NSFR).

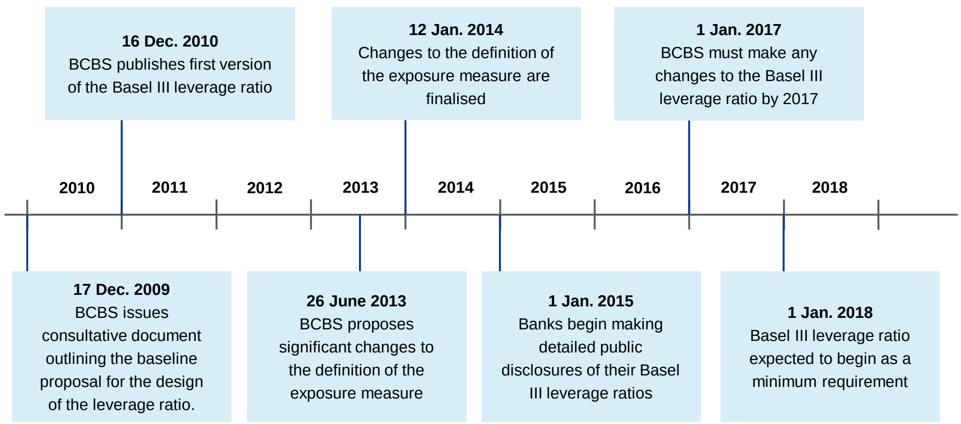
The next section outlines the Basel III LR framework and associated key regulatory milestones. The second section presents theoretical results on the trade-off between higher loss-absorbing capacity and additional risk-taking induced by an LR requirement. The final section presents empirical evidence from EU banks that the introduction of the LR requirement into the regulatory framework should lead to more stable banks, despite slightly higher bank risk-taking.

The leverage ratio in the Basel III capital framework

The build-up of excessive leverage (both on and off-balance sheet) was identified as a major driver in the recent global financial crisis. The BCBS envisages the LR playing a key role in avoiding such adverse developments in the future. The LR is a non-risk-based capital measure and is defined as Tier 1 capital over a bank's total exposure measure, which consists of both on and off-balance-sheet items.[3] It is widely expected that the LR will become a Pillar 1 requirement for banks under Basel III, ever since the BCBS issued a consultative document in December 2009[4] outlining a baseline proposal for the design of the LR. Following further public consultations and revisions to the design, the BCBS issued the (almost) final LR framework in January 2014. The BCBS is currently testing a minimum Tier 1 LR of 3% until 1 January 2017 with a view to migrating to a Pillar 1 requirement on 1 January 2018.[5] Chart A.1 summarises the key regulatory milestones related to the LR which will be used in the empirical analysis to motivate the econometric set-up to identify the impact of an LR requirement on bank risk-taking.

Chart A.1

Key dates on the introduction of the Basel III leverage ratio



Source: Grill, Lang and Smith (2015).

3 See BCBS (2014a). For on-balance-sheet items, the exposure measure generally relies on accounting values, whereas it uses a specific treatment for derivatives and securities financing transactions.

4 BCBS (2009), *Strengthening the resilience of the banking sector*, *Consultative Document*, December.

5 See BCBS (2014a). The BCBS will review the calibration of a minimum LR requirement and make any final adjustment to it by 2017. In Europe, the EBA is currently preparing a report on the impact and the potential calibration of the LR. Based on the results of the report, the European Commission is to submit a report on the impact and effectiveness of the LR to the European Parliament and the Council by the end of 2016.

The benefits and (potential) costs of a leverage ratio constraint

There are various reasons why an LR requirement may be beneficial. Most importantly, highly leveraged banks have lower loss-absorbing capacity and are arguably less resilient to shocks. This is of particular concern if the build-up of excessive leverage concerns the entire banking sector, as witnessed in the run-up to the financial crisis. By capping the total amount of leverage banks can achieve, an LR requirement ensures that banks with a large share of low risk-weighted assets hold additional loss-absorbing capacity. The LR may therefore present a better measure for containing aggregate risk and protecting against rare (and highly correlated) losses in the financial system which are not fully covered under the risk-based capital framework.[6]

During the financial crisis, it was also observed that highly leveraged banks that experienced failure or distress were still showing strong risk-based capital ratios.[7] Thus, by providing a simple non-risk-based capital requirement, the LR can potentially alleviate issues surrounding model risk in the calculation of risk-weights or even the outright manipulation of risk-weights.[8] Indeed, the crisis has shown that there can be circumstances under which sophisticated concepts for risk measurement fail and there are also indications of deliberate optimisation of risk-weighted assets by banks ("gaming").[9]

Notwithstanding these potential benefits, the LR has been criticised by market participants and other stakeholders. The main concern relates to the risk-insensitivity of the LR: assets with the same nominal value but of different riskiness are treated equally and face the same capital requirement under the non-risk-based LR.[10] Given that an LR requirement has a skewed impact, binding only for those banks with a large share of low risk-weighted assets on their balance sheets, the move away from a solely risk-based capital requirement may thus induce these banks to increase their risk-taking, potentially offsetting the benefit gained from requiring them to hold more capital.[11] While these concerns are generally valid, they need to be assessed

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[6] See BCBS (2014b), *Capital floors: the design of a framework based on standardised approaches, Consultative document*, December.

[7] See BCBS (2014a).

[8] Kiema and Jokivuolle (2014) show that an LR requirement can improve bank stability in the presence of model risk. See Kiema, I. and Jokivuolle, E. (2014) "Does a leverage ratio requirement increase bank stability?", *Journal of Banking & Finance*, Vol. 39(1), pp. 240-254. In addition, Blum (2008) shows in an adverse selection model that a non-risk-based capital ratio can improve bank stability by reducing the incentive to conceal true risk levels. See Blum, J. (2008), "Why 'Basel II' may need a leverage ratio restriction", *Journal of Banking & Finance*, Vol. 32(8), pp. 1699-1707.

[9] See Behn, M., Haselmann, R. and Vig, V. (2014), *The limits of model-based regulation*, Working Paper, August.

[10] See, e.g. ESRB (2015), *The ESRB Handbook on Operationalising Macroprudential Policy in the Banking Sector* – addendum on macroprudential leverage ratios.

[11] This concern has been voiced predominantly by banks. For example, the ex-chief executive of Barclays, Antony Jenkins, expressed concern about LRs, saying they needed "to be interpreted with care to avoid unintended consequences such as credit restriction and asset quality dilution" (available at http://www.theguardian.com/business/2013/jun/28/barclays-warns-on-new-capital-rules). Other examples include the Swedish financial supervisory authority (Finansinspektionen) noting that, "If non-risk-sensitive capital requirements – such as a leverage ratio requirement or standardised floor – are set at a level that makes them the binding capital restriction, Sweden may end up with a smaller, but riskier banking system … A high leverage ratio requirement could consequently result in less financial stability" (available at http://www.fi.se/upload/90_English/95_Supervision/framtida-kapitalkrav-juni-2015-eng.pdf).

in the context of the overall prudential framework (rather than in isolation): increased risk-taking should raise banks' risk-weighted assets, provided that the risk weights are properly determined, so that at some point the risk-weighted capital framework becomes binding again. Hence, the potential for a marginal increase in risk-taking owing to an LR requirement should be limited as long as both approaches to capital regulation are mutually reinforcing.

The above discussion therefore suggests that a trade-off from imposing an LR requirement should exist, even when abstracting from model risk and risk-weight manipulations. On the one hand, it should enhance banks' loss-absorbing capacity and their resilience; on the other hand, there is a potential incentive to increase risk. To analyse this trade-off between risk-taking and higher loss absorption more formally, it is useful to consider a simple micro model of bank risk-taking similar in spirit to Dell'Ariccia et al. (2014).[12] The proposed model explicitly considers a situation in which there exists both a risk-weighted capital requirement and an LR requirement, and hence banks are subject to the maximum of the two capital charges. The box describes the theoretical set-up of the model in more detail.

The model yields two key results. First, imposing an LR constraint incentivises banks to modestly increase risk-taking. This occurs because the non-risk-based nature of the LR effectively reduces the marginal cost of risk-taking. Nevertheless, this increase in risk-taking is not unbounded. On the one hand, the risk-based capital framework underlies the LR constraint, such that if the bank takes on too much additional risk it will simply move back into the risk-based capital framework. On the other hand, an offsetting effect on risk-taking incentives exists because banks are required to hold more capital, as this to some extent makes them more cautious (banks have more "skin in the game"). Consequently, the second key result from the model suggests that imposing an LR requirement should be beneficial for bank stability as the positive effect of additional loss-absorbing capacity of banks dominates the negative effect of increased risk-taking. In particular, the model suggests that if the LR requirement is not set at an excessive level, adding an LR constraint to the risk-based capital framework will both weakly decrease banks' probability of failure and, if the distribution of banks is not such that the majority of banks are concentrated around the LR minimum requirement, which is arguably the case in reality, strictly decrease expected losses.[13] The model therefore suggests two empirically testable hypotheses.

1. Introducing an LR requirement incentivises those banks bound by it to modestly increase risk-taking.

2. Obliging banks to hold greater capital via an LR requirement is beneficial for bank stability.

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[12] Dell'Ariccia, G., Laeven, L. and Marquez, R. (2014), "Real interest rates, leverage, and bank risk-taking", *Journal of Economic Theory*, Vol. 149, pp. 65-99.

[13] A weak decrease includes circumstances in which there is neither an increase nor a decrease. A strict decrease includes only those circumstances in which there is a decrease.

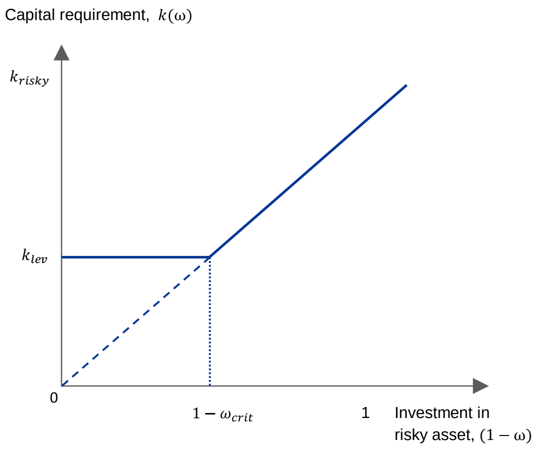
Box

Theoretical considerations on the leverage ratio: risk-taking vs. loss-absorbing capacity[14]

Consider a one-period economy with three types of agent: banks, investors and depositors. Banks raise funds from both depositors and equity holders (who both have outside options), and use these funds to invest in a portfolio of assets. Banks can choose between two assets: a (relatively) safe asset and a risky asset. Denote by ω investment in the safe asset and $(1-\omega)$ investment in the risky asset.[15] The risky asset is termed as such since, although it offers a greater expected return and has the potential for a larger payoff, it is more likely to fail (and thus result in a loss) than the safe asset. In particular, there exist two possible states of nature: state s_1 can be thought of as a good state and occurs with probability μ, while state s_2 can be thought of as a bad state and occurs with probability $(1-\mu)$. The safe asset returns $R_1 \geq 1$ if state s_1 occurs and $(1-\lambda_1) \in (0,1)$ if state s_2 occurs. On the other hand, in state s_1, the risky asset returns $R_2^h > R_1$ with probability π and $(1-\lambda_2) \in (0,1)$ with probability $(1-\pi)$, while in state s_2 the risky asset returns $(1-\lambda_3) \in (0,1)$ with probability π, and 0 otherwise.[16] The key friction inherent in the model is that there is the chance of a correlated system-wide shock in state s_2. While it has a small probability of occurring, it hits both the safe and the risky asset.[17] Therefore, as discussed above, the assumed friction relates to one of the key reasons for the introduction of an LR requirement in Basel III.[18]

Chart A.2

The kinked nature of capital requirements



Source: Grill, Lang and Smith (2015).

Now consider a situation in which there exists both a risk-weighted capital requirement and an LR requirement, and hence banks are subject to the maximum of the two capital charges. The risk-weighted requirement, denoted $k(\omega)$, depends on the risk choice of the bank. The risky asset, since it is more likely to incur losses, requires a higher capital charge under the risk-based requirement. Thus the more the bank invests in the risky asset, the higher its capital requirement. By contrast, under the LR, denoted k_{lev}, the capital requirement is independent of how much the bank invests in the safe or the risky asset: banks are required to hold this capital independent of the riskiness of their portfolio. This capital framework leads to a kinked capital requirement as depicted in Chart A.2. Since the risk-based requirement increases in holdings of the risky asset, at low-risk holdings, the risk-based capital requirement lies below the LR requirement (see the dotted line). As holdings of the risky asset increase, the risk-based requirement increases until at some level, denoted $(1-\omega_{crit})$ in the chart, it starts to exceed the LR requirement.

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14 For a more detailed exposition, see Grill, Lang and Smith (2015).

15 The size of the bank's balance sheet is normalised to one.

16 It is assumed that the losses are greater in the risky asset, so $\lambda_1 < \lambda_2 < \lambda_3$.

17 The term $(1-\mu)$ is therefore assumed to be small.

18 Concerns related to gaming of risk-weights and model risk are abstracted from; including these considerations in the analysis would merely strengthen the argument since the risk-based framework is inherently susceptible to them. Instead, the analysis concentrates on the LR's ability to cover risks not fully captured under a solely risk-based framework.

As noted in the main text, the model yields two key results. First, imposing an LR requirement incentivises banks to increase risk-taking. This can be seen by comparing the first order condition (FOC) when the model is solved under a solely risk-based capital requirement, and when an LR constraint is added. Under a solely risk-based capital requirement, the FOC characterising the optimal risk-choice is:[19]

$$\mu[\pi R_2^h + (1-\pi)(1-\lambda_2) - R_1] = -\rho k'(\omega) - \mu k'(\omega) - c'(\omega)$$

The FOC shows that banks increase risk-taking until the marginal return from greater investment in the risky asset (i.e. the left-hand side of the equation) equals the marginal cost (i.e. the right-hand side). What should be noted is that the marginal cost incorporates the need to increase capital when taking on further risk. This can be seen in the terms containing $k'(\omega)$. This is by definition of the risk-based capital requirement in the model, as it is a function of the bank's risk level. Since capital is a relatively costly source of funds, this to some extent disincentivises risky investment. Indeed, there is a trade-off which the bank can exploit: by choosing to hold less risk, the bank somewhat offsets this lower return by its ability to lower expensive capital.

With a non-risk-based LR as the binding constraint, all terms related to the risk-weighted capital requirement, $k(\omega)$, disappear, since increasing risk no longer requires the bank to increase capital. Formally, the FOC becomes:[20]

$$\mu[\pi R_2^h + (1-\pi)(1-\lambda_2) - R_1] + (1-\mu)Y = -c'(\omega)$$

Removing this dependence on risk means that banks can shift into the risky asset without having to hold additional capital. In other words, the marginal cost of risk-taking declines. At the same time, since banks now survive slightly larger shocks, they start to internalise and attach value to these returns they otherwise would have ignored. This can be seen via the addition of Y in the above FOC and can be seen as what is termed in the literature as a "skin-in-the-game" effect. There are thus two opposing effects. The first effect (i.e. removing the link between risk and capital), incentivises greater risk-taking, whereas the second effect reduces this incentive. Yet this skin-in-the-game effect is small and the first effect dominates.

Nevertheless, this is an isolated analysis and leads to the second key result. Although banks are taking on greater risk, they are at the same time holding a greater capital buffer which means that they can absorb greater losses. Taking these considerations together, the model suggests that if the LR is not set excessively high, imposing an LR will both weakly decrease banks' probability of failure and, if the distribution of banks is not such that the majority of banks are concentrated around the LR minimum, strictly decrease expected losses. [21] Therefore, the increase in loss-absorbing capacity outweighs the increase in risk-taking. Chart A.3 illustrates how expected losses and the

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19 Where ρ is equal to the opportunity cost of equity holders, and $c(\omega)$ is a convex investment cost à la Allen and Gale. See Allen, F. and Gale, D. (2000), "Bubbles and Crises", *The Economic Journal*, Vol. 110, Issue 460, pp. 236-255.

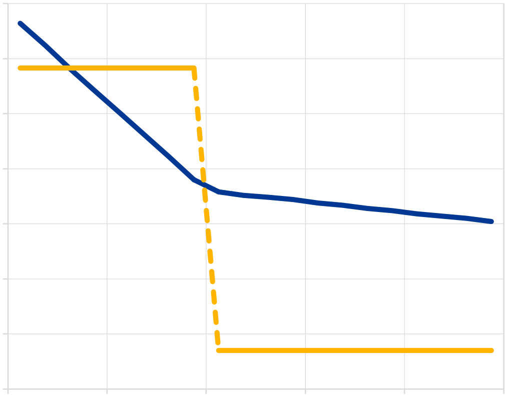
20 Where Y can be equal to 0, $\pi(\lambda_3 - \lambda_1)$ or $[\pi(\lambda_3 - \lambda_1) + (1-\pi)(1-\lambda_1)]$ depending on the parameter values, and particularly the exact value of the LR, since with higher capital, banks may survive larger losses and, as a result, take this return into consideration.

21 The caveat on excessively high levels of the LR arises due to the outside option available to equity investors. This outside option is larger than that of depositors. Since investors require a higher return, at some point, obliging banks to hold so much capital will force them to go beyond their optimal risk choice just to meet equity holders' requirements. The model therefore issues a warning about the absolute level of the LR, since if risk-taking is not sufficiently constrained because banks are forced to go beyond their optimal risk choice, the LR can cease to be beneficial.

Chart A.3

Leverage ratio, expected losses and default

(x-axis: leverage ratio)



Source: Grill, Lang and Smith (2015).
Notes: There exists a discrete jump in both series owing to the discrete nature of the asset payoff structure. The jump occurs at the point where the bank starts to survive larger shocks in the bad state s_2.

probability of default depend on the level of the LR. As the LR requirement increases and starts to bind, both expected losses and the probability of default decline.

The above result is obtained because although banks increase their risk-taking, this increase is not unbounded. It was already noted that an offsetting effect exists by obliging banks to hold greater capital – the skin-in-the-game effect – but there is also a limit to how much additional risk a bank can take on. Despite the LR requirement, the risk-based framework still underlies the capital framework. Thus, if the bank takes on too much additional risk, it will simply move back into the risk-based framework. Hence, as long as the risk-based requirement applies alongside the LR, it acts to constrain the risk-taking incentive.

Empirical evidence: higher risk-taking but more stable banks

The empirical analysis follows in three stages. First, the joint effects of the LR and risk-taking on bank distress probabilities are estimated in order to quantify the risk/stability trade-off. Second, it is examined whether there is any evidence that banks with low LRs started to increase their risk-taking after the announcement of the new Basel III regulatory regime. Finally, the results from the first two stages of the empirical analysis are combined in a counterfactual simulation to gauge whether an LR requirement is beneficial for bank stability, i.e. whether the estimated increase in risk-taking is dominated by the benefits of increasing loss-absorbing capacity.

The dataset for the empirical analysis consists of a large unbalanced panel of more than 500 EU banks covering the years 2005-14. The dataset has three main building blocks: (i) a large set of bank-specific variables based on publicly available financial statements from SNL Financial; (ii) a unique collection of bank distress events that covers bankruptcies, defaults, liquidations, State aid cases and distressed mergers from various publicly available data sources and; (iii) various country-level macro-financial variables from the ECB's Statistical Data Warehouse. The dataset builds upon and expands the dataset described in Betz et al. (2014).[22]

In a first step, the unique dataset of EU bank distress events is used in a discrete choice modelling framework to analyse the joint effects of the LR and risk-taking on bank stability, while controlling for other relevant bank-specific and country-level variables. Since data for the Basel III definition of the LR is unavailable, as the LR

[22] Betz, F., Oprica, S., Peltonen, T. and Sarlin, P. (2014), "Predicting distress in European banks", *Journal of Banking & Finance*, Vol. 45, pp. 225-241.

proxy, the ratio of Tier 1 equity to total assets is used, which has been shown to correlate very highly with the Basel III regulatory definition of the LR. As a measure of bank risk-taking, the ratio of risk-weighted assets to total assets is taken.[23] Various versions of the following logit model with time and country fixed effects are estimated, where the left-hand-side variable is the binary distress indicator for bank i, located in country j, in year $t+1$; γ_j and λ_{t+1} are country and time fixed effects respectively; and $X_{i,j,t}$ and $Y_{j,t}$ are vectors of bank-specific and country-specific control variables that may also include lags and differences: [24]

$$Pr\left(I_{i,j,t+1}=1\right)=\frac{\exp\left(\alpha+X'_{i,j,t}\theta+Y'_{j,t}\varphi+\gamma_j+\lambda_{t+1}\right)}{1+\exp(\alpha+X'_{i,j,t}\theta+Y'_{j,t}\varphi+\gamma_j+\lambda_{t+1})}$$

Table A.1 shows the results of the first stage empirical exercise.[25] As can be seen, the LR is a very important indicator for determining bank distress probabilities; both economically and statistically. For example, consider models 1 and 2. Quantitatively they suggest that a 1 percentage point increase in a bank's LR is associated with around a 35-39% decline in the relative probability of distress to non-distress (the odds ratio).[26] This is much larger than the marginal impact from taking on greater risk. The coefficient estimates suggest that increasing a bank's risk-weighted assets ratio by 1 percentage point is associated with an increase in its relative distress probability of only around 1-3.5%. This demonstrates the relative importance of the LR in determining bank distress probabilities. The other models in Table A.1 show that the results are robust to introducing non-linear effects in the LR and risk-weighted assets ratio and to different bank samples. Chart A.4 illustrates the estimated non-linear effects from model 4 graphically. Increasing the LR from low levels seems to be of considerable benefit to bank stability, but as a bank's LR reaches around 5% the benefits of increasing it further start to diminish slightly. This suggests that there may be considerable benefit in introducing the LR requirement with a modest calibration, but advises caution about raising the LR requirement too high as suggested by our theoretical model, since the benefit starts to tail off.

23 While the ratio of risk-weighted assets to total assets is an imperfect measure of true risk-taking, it is the most direct measure, and it is the risk-taking measure that should be affected by the introduction of an LR requirement. In addition, control variables for the calculation method of risk weights are included in the empirical models, which should partly account for the fact that risk-weight levels appear to differ systematically between the standardised approach and the internal ratings-based approach for determining risk-weights.

24 A logit model is used instead of a probit model because the fatter-tailed error distribution better matches the empirical frequency of bank distress events. See van den Berg, J., Candelon, B. and Urbain, J. (2008), "A cautious note on the use of panel models to predict financial crises", *Economic Letters*, Vol. 101, pp. 80-83. While the early-warning literature has commonly used a pooled logit approach (see, e.g. Lo Duca, M. and Peltonen, T. (2013), "Assessing systemic risks and predicting systemic events", *Journal of Banking & Finance*, Vol. 37(7), pp. 2183-2195), here, both time and country fixed effects are also controlled for since in-sample fit and unbiased coefficient estimates are more important for the analysis than optimising out-of-sample predictive performance.

25 The following bank-specific variables are controlled for: non-performing loans (NPLs) to total assets, reserves to impaired loans, pre-tax return on assets (ROA), interest expenses to liabilities, the loan-to-deposit ratio, bank size (via the log of total assets), the relevant Basel regulatory regime at the time and the method used by the bank to calculate risk-weighted assets. The following macro-financial variables are controlled for: change in ten-year yield spread relative to the Bund, gross government debt to GDP, the unemployment rate, real GDP growth, the inflation rate, private sector credit flow to GDP, the credit to GDP ratio, the change in issued bank debt to total liabilities, and the stock market growth rate. All variables are lagged by one year to avoid endogeneity.

26 For a detailed discussion on the interpretation of logit coefficients, see Cameron, A. and Trivedi, P. (2005), *Microeconometrics: methods and applications*, Cambridge University Press.

Table A.1

Estimated impact of the leverage ratio and risk-taking on bank distress probabilities

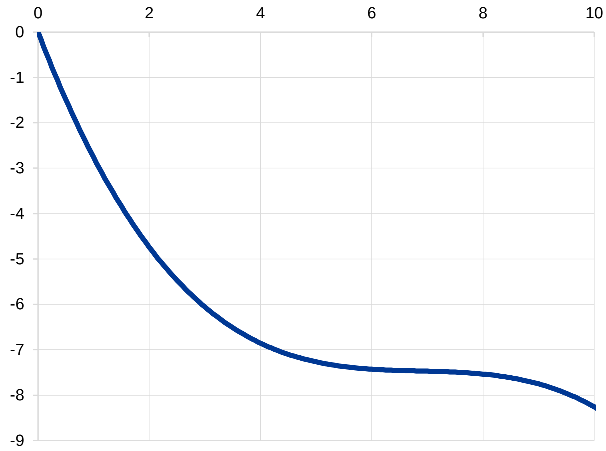
Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Leverage ratio proxy	-0.510***	-0.427***	-1.046***	-3.206***	-2.865***	-3.957***	-5.188**
Leverage ratio proxy, squared			0.054***	0.463***	0.420**	0.580***	0.465
Leverage ratio proxy, cubed				-0.023**	-0.021**	-0.028***	-0.014
RWA/total assets	0.035***	0.011	0.166***	0.202***	0.188***	0.251***	0.406**
RWA/total assets, squared			-0.001***	-0.002***	-0.002***	-0.002***	-0.002
Sample	All	All	All	All	Euro area	Western Europe	W. Europe excl. GIIPS
# Observations	1,661	1,661	1,661	1,661	1,234	1,334	674
Pseudo R2	0.284	0.410	0.430	0.437	0.431	0.408	0.559
AUROC	0.870	0.926	0.929	0.930	0.926	0.918	0.961
Country and time fixed effects	No	Yes	Yes	Yes	Yes	Yes	Yes
Bank-specific and macro-financial controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Source: Grill, Lang and Smith (2015) based on data from SNL Financial, ECB Statistical Data Warehouse, and bank distress events defined as in Betz et al. (2014).
Notes: Logit model estimates obtained on binary bank distress variable. The numbers in the table are logit coefficients. *** indicates significance at the 1% level, ** at the 5% level, and * at the 10% level. Significance based on clustered robust standard errors. "RWA" refers to risk-weighted assets. "All" means the estimation is based on the entire sample. Euro area includes only those banks which are based in the euro area. Western Europe includes only banks from the following countries: Belgium, Denmark, Germany, Ireland, Greece, Spain, France, Italy, Luxembourg, Netherlands, Austria, Portugal, Finland, Sweden and the United Kingdom. "W. Europe excl. GIIPS" refers to the Western Europe sample excluding banks based in Greece, Ireland, Italy, Portugal and Spain.

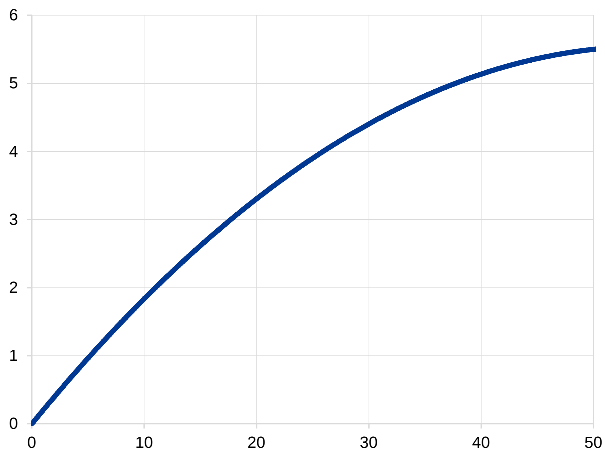
Chart A.4

Illustration of the non-linear effects of the leverage ratio and risk-taking on bank distress probabilities

(x-axis: leverage ratio; y-axis: log relative distress probability)



(x-axis: RWA/total assets; y-axis: log relative distress probability)



Source: Grill, Lang and Smith (2015) based on data from SNL Financial, ECB Statistical Data Warehouse, and bank distress events defined as in Betz et al. (2014).
Notes: The log relative distress probability is equal to the log of the probability of distress divided by the probability of non-distress. Specifically, denote the probability of distress by p, it is equal to $\log\left(\frac{p}{1-p}\right)$. For illustrative purposes, in generating these charts, all variables except the specified variable are set to zero. "RWA" refers to risk-weighted assets.

To identify the impact of an LR requirement on banks' risk-taking behaviour, the panel dimension of the dataset is used in combination with the timing of the Basel III LR announcements, as described above. To achieve identification, the announcement of the LR requirement is considered as a treatment that only affects a subset of banks, i.e. only banks below the LR requirement. The econometric approach is therefore a difference-in-difference type analysis in which the effect of the LR constraint on risk-taking is estimated through a treatment dummy, while controlling for a large set of bank-specific and country-level variables that capture systematic differences in bank behaviour pre- and post-treatment. Specifically, various versions of the following general panel model are estimated, where the left-hand-side variable is the ratio of risk-weighted assets to total assets (either in levels or first differences) for bank i, located in country j, in year t; μ_i represents bank fixed effects; $\varepsilon_{i,j,t}$ is an error term; and the other variables are defined as in the model to estimate bank distress probabilities:

$$y_{i,j,t} = \alpha + \beta T_{i,j,t} + X'_{i,j,t}\theta + Y'_{j,t}\varphi + \mu_i + \lambda_t + \varepsilon_{i,j,t}$$

In the risk-taking model above, $T_{i,j,t}$ is the treatment dummy of interest. It is set to 1 for a given bank and year if its LR in the previous year was below the (planned) regulatory minimum LR, but only for the years following the first announcement of the Basel III LR. The treatment dummy is set to 0 otherwise.[27] Thus, the coefficient of interest for the second stage of the empirical analysis is β, which measures how the announcement of an LR constraint has affected the risk-taking behaviour of banks. 2010 is set as the treatment start date in reference to the December 2009 BCBS consultative document (BCBS (2009)) that outlined the baseline proposal for the LR (see the timeline presented in Chart A.1). Moreover, 3% is taken as the relevant LR threshold since the BCBS is currently testing a minimum 3% LR until 1 January 2017.

Table A.2 presents the results of the second stage empirical analysis.[28] As can be seen from the table, the results confirm that since the Basel III LR framework was announced, EU banks with low LRs have slightly increased their risk-taking, as measured by their risk-weighted assets to total assets ratio. In terms of the quantitative impact, the point estimates for the treatment effect of a 3% LR requirement suggest that banks bound by the LR requirement increased their risk-weighted assets ratio by around 1.5 to 2 percentage points more than they otherwise would have. Furthermore, while the LR requirement seems to slightly incentivise risk-taking, the strengthening of the risk-based capital framework under Basel III seems to have the opposite impact.[29] Therefore the small estimated effects on bank risk-taking of the LR requirement are not a result of strengthening the risk-based capital framework since this effect is controlled for. Table A.2 further illustrates that the results are robust to the introduction of bank and time fixed effects, different bank samples and whether the dependent variable is modelled in differences (columns 1-

[27] A crucial assumption underlying the empirical approach is that banks already started to adjust their risk-taking behaviour after the announcement of the LR constraint, i.e. before it actually migrates to a binding Pillar 1 regulatory requirement. However, there is ample anecdotal evidence that supports this assumption.

[28] In the models, the following bank-specific variables are controlled for: bank size (via the log of total assets), net interest margin, pre-tax ROA, NPLs to total assets, the loans to total assets ratio, the relevant Basel regulatory regime at the time and the method used by the bank to calculate risk-weighted assets. The following macro-financial variables are also controlled for: real GDP growth, inflation, the change in the unemployment rate, stock market growth, financial sector debt, the credit to GDP ratio, the ten-year yield spread relative to the Bund, gross government debt to GDP and house price growth.

[29] The risk-weighted capital dummy is set similarly to the LR dummy. It is set equal to 1 for a given bank and year if its Tier 1 ratio in the previous year was below 10%, but only for years after 2009 in reference to the Basel III regulatory overhaul. The treatment dummy is set to 0 otherwise.

4) or levels (columns 5-7).[30] Furthermore, the results remain robust to various other tests, both quantitatively and in terms of significance, which are not reported here for the sake of brevity.[31]

Table A.2

Estimated impact of a leverage ratio constraint on bank risk-taking

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
LR dummy	1.748***	1.678***	2.217***	1.713**	1.340**	1.657*	1.973**
Risk-weighted capital dummy	-2.335***	-2.394***	-2.556***	-2.212***	-1.023**	-0.687	-0.363
Sample	All	W. Europe	SSM	All	All	All	All
# Observations	2,711	2,325	646	2,550	2,795	1,801	1,801
# Banks	617	529	107	583	571	474	474
R-squared	0.076	0.086	0.111	0.092	0.535		
Bank and time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank-specific and macro-financial controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dependent variable	Differenced	Differenced	Differenced	Differenced	Level	Level	Level
Lagged dependent	No	No	No	Yes	Yes	Yes	Yes
Estimation method	FE	FE	FE	FE	FE	GMM	GMM
AR1-p						0.000	0.000
AR2-p						0.785	0.790
Hansen-p						0.495	0.192

Source: Grill, Lang and Smith (2015) based on data from SNL Financial and ECB Statistical Data Warehouse.
Notes: The dependent variable is the risk-weighted assets to total assets ratio either in differences (columns 1-4) or levels (columns 5-7). "All" means the estimation is based on the entire sample. "W. Europe" includes only banks from the following countries: Belgium, Denmark, Germany, Ireland, Greece, Spain, France, Italy, Luxembourg, Netherlands, Austria, Portugal, Finland, Sweden and the United Kingdom. The sample SSM includes only significant banks that are supervised directly by the ECB under the Single Supervisory Mechanism. Columns 6-7 are estimated using GMM. In column 6, instruments are the previous and further lags of the dependent variable and bank-specific characteristics. In column 7, instruments are the previous lag to the fifth lag of the same variables. Macro variables and Basel regime variables are viewed as exogenous. *** indicates significance at the 1% level, ** at the 5% level, and * at the 10% level. Significance based on clustered robust standard errors.

To shed more light on banks' reactions to the Basel III LR announcement, the risk-taking regressions were also re-estimated with the change in a bank's LR as the dependent variable to see if treated banks were increasing their LRs at the same time as taking on further risk. This indeed seems to have been the case, with estimates of around a 0.5-1 percentage point greater increase in a bank's LR than otherwise would have happened.[32] This finding also provides support for the assumption that banks already started to react to the LR announcement. To summarise, while treated banks may have increased their risk-weighted assets ratios by around 1.5-2 percentage points more, they also increased their LRs by around

[30] Fixed effects (FE) regression and generalised method of moments (GMM) are both estimated since a lagged dependent variable is introduced in the model. In the FE regressions all variables are lagged by one period to avoid endogeneity issues. In the GMM estimation, contemporaneous variables are used but those that are considered as endogenous are instrumented. In particular, the GMM estimation takes macro variables and the Basel regime variable indicators as exogenous; all other variables are instrumented using lags of the variable in question.

[31] In particular, the following exercises were performed. First, a regression discontinuity design was performed such that only banks around the 3% LR minimum were included in the regression (bandwidth determined via the Imbens and Kalyanaraman (2012) algorithm. See Imbens, G. and Kalyanaraman, K. (2012), "Optimal Bandwidth Choice for the Regression Discontinuity Estimator", *Review of Economic Studies*, Vol. 79(3), pp. 933-959). This goes some way to addressing the potential concern that banks with vastly different LRs are fundamentally different and that this is not adequately captured via fixed effects and control variables. Second, banks with LRs between 3-5% were dropped as these banks are potentially fuzzy when it comes to classifying them as treated or control group banks, given that the LR requirement is not guaranteed to be at 3%. The analysis was then rerun on this subsample. Third, different LR threshold levels (up to 5%) were also tested for. The results are robust to all exercises.

[32] Table omitted for the sake of brevity.

0.5-1 percentage point more than they otherwise would have done over the period under consideration. This is a considerably higher increase in a bank's capital position than what would be required under the risk-based capital framework to cover the estimated increase in risk-weighted assets.

The two previous empirical exercises thus suggest that while bound banks slightly increase risk-taking with an LR requirement, the increase in their Tier 1 to assets ratio appears more important from a bank stability perspective. To analyse this more formally, the results from specification 4 of the bank distress model (the most complete model) are combined with the estimated increase in risk-taking from the second-stage empirical exercise in a counterfactual simulation. Using the coefficient estimates, the change in distress probabilities for all banks below the LR minimum (or target level) are simulated, assuming that these banks increase their LRs by the required amount to reach the minimum (or target level), but at the same time increase their risk-weighted assets by the estimated amount. To allow for a conservative assessment, the upper range of the estimated increase in risk-taking is assumed, i.e. a 2 percentage point increase in the risk-weighted assets ratio. For robustness purposes, a 4 and 6 percentage point increase in the risk-weighted assets ratio is also tested. The simulation is performed for a 3%, 4% and 5% LR minimum (or target level).

Table A.3

Estimated reduction in distress probabilities from the introduction of a leverage ratio constraint

LR requirement:	**3%**	**4%**	**5%**	**4%**	**5%**	**5%**
Banks with an LR of:	**Less than 3%**			**Between 3-4%**		**Between 4-5%**
$\Delta(RWA/TA) = 2$	-7.698***	-10.532***	-10.681***	-3.312***	-6.236***	-3.001***
$\Delta(RWA/TA) = 4$	-6.593**	-10.456***	-10.678***	-2.203*	-6.151***	-1.868*
$\Delta(RWA/TA) = 6$	-5.187*	-10.344***	-10.674***	-0.784	-6.026***	-0.442

Source: Grill, Lang and Smith (2015) based on data from SNL Financial, ECB Statistical Data Warehouse, and bank distress events defined as in Betz et al. (2014).
Notes: Average simulated change in distress probability for the relevant banks in the sample. The numbers represent the average percentage point change in distress probability from increasing a bank's LR to the stated percentage while at the same time increasing its risk-weighted assets to total assets ratio by the stated amount. This is done separately for the sample of banks with an LR less than 3%, between 3-4% and between 4-5%. Significance is based on bootstrapped standard errors on 10,000 replications. "RWA" refers to risk-weighted assets. "TA" refers to total assets. *** indicates significance at the 1% level, ** at the 5% level, and * at the 10% level.

Table A.3 reports mean estimated figures from the simulations, so the numbers can be read as the average percentage point change in distress probability for the relevant sample of banks between 2005 and 2014. Since increasing the LR minimum (or target level) increases the sample of banks below this minimum (or target level), in order to ensure comparability across simulations, results are reported separately for the sample of banks with an LR less than 3%, between 3-4% and between 4-5%. The results demonstrate that bank distress probabilities should significantly decline with an LR requirement, even when taking into account much higher increases in risk-taking than were estimated. For example, Table A.3 shows that assuming a 3% LR target and an increase in the risk-weighted assets ratio of 2 percentage points, the average decline in distress probabilities would be 7.7 percentage points for the given sample. If the increase in the risk-weighted assets ratio is assumed to be 6 percentage points, the average decline in distress probabilities would still be 5.2 percentage points. The simulation results therefore illustrate that the beneficial impact of higher capital holdings from an LR requirement should more than outweigh the negative impact of increased risk-taking, thus leading to more stable banks.

Concluding remarks

Theoretical considerations and empirical evidence for EU banks suggest that the introduction of an LR requirement into the Basel III regulatory framework should lead to more stable banks. This special feature has shown that although there is indeed an increased incentive to take risk once banks become bound by the LR, this increase is more than outweighed by the synchronous increase in loss-absorbing capacity attributable to higher capital. The analysis therefore supports the introduction of an LR requirement alongside the risk-based capital framework. The analysis further suggests that the LR and the risk-based capital framework are mutually reinforcing as they each cover risks which the other is less able to capture; ensuring banks do not operate with excessive leverage and, at the same time, have sufficient incentives to keep risk-taking in check.