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Abstract

We assess the impact of the leverage ratio capital requirements on the risk-taking behaviour of banks both theoretically and empirically. We use a difference-in-differences (DiD) setup to compare the behaviour of UK banks subject to the leverage ratio requirements (LR banks) to otherwise similar banks (non-LR banks). Conceptually, introducing binding leverage ratio requirements into a regulatory framework with risk-based capital requirements induces banks to reoptimise, shifting from safer to riskier assets (higher asset risk). Yet, this shift would not be one-for-one due to risk-weight differences, meaning the shift would be associated with a lower level of leverage (lower insolvency risk). The interaction of these two changes determines the impact on the aggregate level of risk. Empirically, we show that LR banks did not increase asset risk, and slightly reduced leverage levels, compared to the control group after the introduction of leverage ratio in the UK. As expected, these two changes lead to a lower aggregate level of risk. Our results show that credit default swap spreads on the five-year subordinated debt of LR banks dropped relative to non-LR banks post leverage ratio introduction.

Key words: Finance, capital regulation, risk-taking, leverage ratio, risk-based requirements.

JEL classification: G01, G21, G28.

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1. Introduction

The leverage ratio was introduced as part of the post 2007-08 financial crisis Basel reforms as a complementing measure to the risk-based capital requirements for banks. By adequately measuring sources of leverage, the ratio aims to prevent the build-up of excessive leverage during credit booms and the corresponding destabilising deleveraging in busts (Basel Committee on Banking Supervision, BCBS, 2014). The leverage ratio captures both on-balance sheet and off-balance sheet exposures of banks in a risk-neutral fashion, without applying risk weights reflecting the riskiness of exposures, as in the risk-based capital requirements. As such, the leverage ratio can reduce the risk of bank runs (Dermine, 2015). When introduced into a regulatory regime with only risk-based requirements, the leverage ratio imposes a sort of floor risk weight for all exposures. This floor would be binding for the low-risk activities with low risk weights (for example, repo lending and client clearing services), increasing the capital base required to support these activities, and making them relatively more costly economically compared to other riskier activities (for instance, lending to SMEs). As a result, the leverage ratio introduction may induce a risk-shifting towards riskier assets, especially when it is the binding constraint (Choi et al., 2020). However, for a constant level of capital, the increase in asset-risk would be accompanied with a lower level of leverage (i.e., lower insolvency risk)[1]. Thus, the impact on the aggregate level of risk relies on the interaction of these two forces. This paper aims to investigate the impact of the leverage ratio on asset risk, insolvency risk and aggregate level of risk of UK banks, since it was introduced to the regulatory regime in 2016. There is a growing literature assessing the impact of the leverage ratio on bank behaviour (for example, Acosta-Smith et al., 2020, and Neamtu and Vo, 2021) and specifically their provision of low-risk activities. Earlier studies (for instance, Baranova et al., 2017, Kotidis and van Horen, 2019, Noss and Patel, 2019, Cenedese et al., 2019, and Bicu-Lieb et al., 2020) suggest that the leverage ratio can affect banks' incentives to engage in low-risk activities. However, more recent analyses (for example, Fatouh et al., 2021, Gerba and Katsoulis, 2021, and Fatouh et al., 2022) indicate that leverage ratio effects are confined to the pricing rather than the amounts of low-risk funding banks provide in the gilt repo market. Fatouh et al. (2022)

[1] This is because riskier assets attract higher risk weights. Hence, shifting 1-to-1 from safer to riskier assets increases risk weighted assets. For a given level of capital, the shift has to be less than 1-to-1, reducing total assets and leverage.

argue that the two views can be reconciled by looking at the period the studies cover. The first set of studies covers early phases just after leverage ratio introduction during which banks were still adapting to the shift in the regulatory regime. Later studies cover later stages when banks had already adjusted their asset mix. As banks subject to the leverage ratio have stronger capital positions, the ratio could have positive effects on low-risk activities provision in stress.

The leverage ratio was introduced as capital requirements in the UK in 2016 and was only applicable to a subgroup of banks. This provides an ideal framework for a difference-in-differences (DiD) empirical exercise. We start our assessment by building a stylised analytical model to illustrate how the leverage ratio introduction affects asset risk, insolvency risk and aggregate level of risk. The model assesses how the introduction of the leverage ratio affects the size and composition of a stylised bank's assets, subject to only risk-based capital requirements. We then test the insights from the theoretical model empirically using a DiD exercise, which compares the risk-taking behaviour of banks subject to the leverage ratio (LR banks) relative to similar banks not subject to it (non-LR banks).

Our theoretical model indicates that, when the leverage ratio is introduced into a risk-based only regulatory regime, a bank with binding leverage ratio requirements could reallocate its resources towards assets with higher risk. This shift would not be one-for-one, due to the higher risk weights the riskier assets attract, making the bank less leveraged.[2] Nevertheless, the presence of the risk shifting assumes that the returns of the riskier assets should be high enough to incentivise banks to reallocate their capital towards them. If the risk and capital-adjusted returns were lower on riskier assets than safer assets, the risk shifting will be limited. Such scenario is more likely to materialise in a low-yields environment, like that after the Great Financial Crisis (GFC), up until the second half of 2021.

Our empirical exercise suggests that LR banks did not increase asset risk, and slightly reduced leverage levels, compared to the control group after the introduction of leverage ratio in the UK. As expected, these two changes led to a lower aggregate level of risk. The DiD results show that credit default swap (CDS) spreads on 5-year subordinated debt of LR banks fell relative to non-LR banks post leverage ratio introduction, suggesting the market viewed LR banks as less risky, especially during COVID stress.

[2] This assumes banks maintain risk weight assets (RWAs) at their pre leverage ratio levels. Hence, reducing assets with 10% risk weight by £1 releases capacity sufficient for a £0.50 increase in assets with 20% risk weights.

The remainder of the paper is as follows. Section 2 provide a background on the leverage ratio framework and its implementation in the UK. Section 3 includes our theoretical model. Section 4 describes our dataset and Section 5 outlines the design of our empirical exercise. Section 6 presents our results, and Section 7 presents robustness checks. Section 8 concludes.

2. Background on the Basel III reforms

In response to the 2007-08 financial crisis, the Basel Committee on Banking Supervision (BCBS) introduced a set of reforms aiming to increase the level of bank regulatory capital and improve its quality, enhance measurement of risk, address excessive leverage and liquidity risk, mitigate systemic risk, and improve bank supervision and market discipline (BCBS, 2017). The reforms included changes to the pre-existing risk-based framework, introducing new capital and liquidity requirements and additional requirements for global systemically important banks (GSIBs), supporting stronger banking supervision (Pillar 2), and enhancing disclosure requirements (Pillar III).[3]

The leverage ratio was a part of the new capital measures introduced in 2010 to mitigate excessive leverage build-up in credit booms and the corresponding destabilising deleveraging in busts. It is equal to Tier 1 capital divided by total leverage ratio exposure measure (LEM). LEM generally follows gross accounting values (i.e., no netting of assets against liabilities), and does not consider collateral (physical or financial) or other credit risk reduction techniques (for example, guarantees). It consists of four main components, (i) on-balance sheet exposures (accounting assets), (ii) off-balance sheet exposures, (for instance, credit facilities), (iii) derivatives exposures,[4] and (iv) securities financing transaction exposures (SFTs), such as repo and repo-like transactions. The leverage ratio framework was first introduced as a requirement in the UK in 2016 and was applicable at the time to banking groups with £50 billion or more in retail deposits.[5] [6] It has since been part of the regulatory regime for banks in the UK, which consists of the same components of the Basel III reforms discussed above.

[3] More details about the Basel III reforms can be found on the website of the Bank for International Settlements (BIS): https://www.bis.org/bcbs/basel3.htm?m=2572.

[4] These exposures differ from derivatives assets or liabilities reported on the financial statements and are calculated using the current exposure method (CEM) or the Standardised Approach for Counterparty Credit Risk (SA-CCR).

[5] Despite the larger retail deposits, a comparable control group in terms of size and business model could be constructed using propensity score matching, as shown in Section 5.2.

[6] The coverage or the scope of application of the leverage ratio framework was expanded to include the ring-fenced subsidiaries of these banking groups (in 2018), and non-ring-fenced subsidiaries (in 2022). From 2023, the framework will be applicable to all banks with foreign exposures of £10 billion or more.

3. The theoretical model

3.1 The baseline model

Consider a bank with two assets, *safe* gilts (S) and *risky* loans (L). The bank is endowed with a fixed amount of equity capital (E) and aims to maximise profits.

$$\pi = r_S S + r_L L - \left(\delta_S(S)\right)S - \left(\delta_L(L)\right)L \qquad (1)$$

where, r_i: gross return on asset i; δ_i: the probability of default on asset i, an increasing function in the size of the asset ($\delta_L > \delta_S$). The bank was subject to risk-based capital requirements set at χ_1 as follows, where w_i is the risk-weight allocated to asset i ($w_L > w_S$):

$$\frac{E}{w_S S + w_L L} \geq \chi_1 \qquad (2)$$

However, the regulator recently introduced LR requirements of χ_2 as follows:

$$\frac{E}{S + \mathrm{L}} \geq \chi_2 \qquad (3)$$

We assess the impact of LR introduction on the optimal allocation between gilts and loans. Since the leverage ratio was applicable at the level of the banking group, both requirements in our model apply to the bank as one unit. However, a bank may choose to apply the requirements to individual business units. We consider this scenario in Appendix A2.[7] Hence, the bank problem is expressed by Equations (1) and (2) prior to the leverage ratio, and Equations (1), (2) and (3) after its introduction. The optimal values of S and L before the leverage ratio introduction are:

$$S^*_{Pre-LR} = \frac{\frac{w_L}{w_S} r_s - r_L + 2\delta_L \frac{E}{w_L \chi_1}}{2\left(\frac{w_L}{w_s}\delta_S + \frac{w_S}{w_L}\delta_L\right)} \qquad (4)$$

[7] When it was introduced, the leverage ratio was applicable at the level of the banking group, rather than individual solo entities or business units. As such, both requirements in our model apply to the bank as one unit (bank-level). Yet, the bank's internal procedures ultimately determine the level at which the requirements apply. The bank may choose to apply the requirements at the bank-level, or at the unit-level (i.e., to individual business units). In the first case, capital is fungible across business lines, whereas in the second the bank endows each line with a specific amount of capital. There is evidence that some banks follow a benchmarking approach to allocate capital to their business units, under which they consider the leverage ratio capital requirements of each unit (for example, Bank of England, 2018). In this case, the leverage ratio would effectively applied at the business unit-level. We consider this scenario in Appendix A2. This was not intended, and the Financial Policy Committee (FPC) of the Bank of England reiterated that the leverage ratio should not be applied to individual activities (Bank of England, 2019).

$$L^*_{Pre-LR} = \frac{\frac{w_S}{w_L} r_L - r_S + 2\delta_S \frac{E}{w_S \chi_1}}{2\left(\frac{w_L}{w_S}\delta_S + \frac{w_S}{w_L}\delta_L\right)} \quad (5)$$

When the leverage ratio is introduced, the bank would be bound by either the risk-based or leverage ratio requirements.[8] In the first case, Equation (5) would be redundant, and the optimal values in Equations (4) and (5) would not change. Meanwhile, if the leverage ratio was the binding constraint, the optimal values of S and L become as follows:

$$S^*_{Post-LR} = \frac{r_s - r_L + 2\delta_L \frac{E}{\chi_2}}{2(\delta_S + \delta_L)} \quad (6)$$

$$L^*_{Post-LR} = \frac{r_L - r_S + 2\delta_S \frac{E}{\chi_2}}{2(\delta_S + \delta_L)} \quad (7)$$

Since $\delta_L > \delta_S$, $w_L > w_S$, $w_L\chi_1 > \chi_2$, and $w_S\chi_1 < \chi_2$, the optimal allocation shifts towards less gilts and more loans, but total assets fall, implying a lower level of leverage. Since the increase in asset-risk is accompanied with lower leverage (insolvency-risk), the leverage ratio's impact on the aggregate level of risk depends on the interaction between these two forces. The aggregate level of risk can be measured by the weighted average probability of default on the two assets:

$$D_{Avg} = \delta_S(S)\frac{S}{S+L} + \delta_L(L)\frac{L}{S+L} \quad (8)$$

If the weighted average probability of default post leverage ratio introduction ($D_{Avg;Post-LR}$) is lower than that pre-LR ($D_{Avg;Pre-LR}$), the bank's aggregate level of the risk falls, and vice versa.

In our empirical exercise, we assess the effects of leverage ratio on asset risk and insolvency risk by comparing the composition of assets in terms of riskiness and the level of leverage for banks subject to the leverage ratio (LR banks) to similar banks outside its scope (non-LR banks). To assess effects on aggregate level of risk, we compare the movements in CDS spreads for LR banks relative to non-LR banks after the introduction of leverage ratio in 2016. As the empirical results later show, the introduction of leverage ratio was associated with lower levels of leverage, but no increase in asset

[8] It would be possible for the bank to be bound by both requirements, if there was an asset with 0% risk weight, which we do not include in our model.

risk is documented. This combination leads to a reduction in the aggregate level of risk, as the results of CDS spreads regressions suggest. The next section (3.2) attempts to explain the divergence of the empirical results from the theoretical insights above.

3.2 Leverage ratio and asset-risk a further look

The predictions above (higher asset-risk and lower leverage) after leverage ratio introduction assume that conditions in the markets for both gilts and loans make it optimal for the banks to switch towards less gilts and more loans. In other words, for the shift from gilts to loans to happen, the market conditions should allow the risk-adjusted-capital-adjusted returns (marginal ROE of an additional £1 of an asset) on the two assets to be similar. That is:

$$\frac{r_s - \delta_S S}{E_S} = \frac{r_L - \delta_S L}{E_L} \qquad (9)$$

If market conditions violate Equation (9), the risk shifting will likely be limited. For instance, assume the left-hand side (LHS) of the Equation (9) is considerably higher than the right-hand side (RHS). Leverage ratio introduction would increase E_s, reducing the LHS. Yet, if the increase in E_s was not large enough, the adjusted return on gilts would remain higher, resulting in no risk shifting. Such scenario is more likely to materialise in a low-yields environment, like that after the Great Financial Crisis (GFC), up until the second half of 2021.[9]

4. Data

Our sample includes 173 UK banking groups, eight of which were subject to the leverage ratio.[10] Our dataset runs from January 2014 to December 2020 on quarterly basis, and comes from two main sources, Bank of England's regulatory returns and Refintiv Eikon®. The regulatory returns contain detailed information about banks, including types of assets/exposures (for example mortgages, loans to businesses, securities, off-balance sheet exposures), risk weighted assets (RWAs), decomposition of leverage ratio total exposures by risk weight buckets, and capital positions. We use this data to assess the leverage ratio effects on asset-risk and levels of leverage. For the aggregate level of risk, we use spreads on 5-year subordinated debt from Refintiv Eikon®. Table 1 shows an overview of the data.

9 See the Appendix A3 for an illustration.

10 These groups are Barclays, HSBC, Lloyds, NatWest (formerly, Royal Bank of Scotland), Standard Chartered Bank, Santander UK, Nationwide Building Society and Virgin Money (formerly, Clydesdale).

Table 1: Descriptive statistics on the data

Variable	No. of Obs.	Mean	Std. Dev.	Min	Max
Size (log of total leverage ratio exposures, LREs)	4,572	21.36647	2.384576	15.17968	28.45957
Log(Core Equity Tier 1)	4,643	18.90637	2.070735	15.03349	25.36766
Log(Tier 1)	4,643	18.93763	2.096483	15.03349	25.53545
Off Balance Sheet exposures (to total LREs)	4,575	0.0604918	0.1661051	0	0.333333
Leverage ratio	4,376	0.0991519	0.0751769	0.0117734	0.4969269
RWA (to total LREs) (%)	4,575	0.993449	28.75438	0	1383.945
Log(Exposures with 0% RW)	4,410	19.30819	2.516401	6.907755	26.42371
Log(Exposures with]0-12% RW)	1,551	20.26682	3.63618	3.871201	27.15942
Log(Exposures with]12-20% RW)	4,449	18.55549	2.621793	4.60517	26.0656
Log(Exposures with]20-50% RW)	4,277	19.68325	2.627352	9.987007	26.773
Log(Exposures with]50-75% RW)	3,074	17.09705	3.747752	2.873565	26.03647
Log(Exposures with]75-100% RW)	4,433	18.90037	2.608926	7.833637	26.23265
Log(Exposures in default)	2,954	16.32741	2.816726	5.433372	24.43558
Log(Mortgages)	3,102	19.93467	2.665834	10.6055	26.59538
Log(Sovereign exp)	4,404	19.81806	2.354258	6.726273	26.94187
Log(Bank loans)	4,490	18.47005	2.072866	9.303831	25.29551
Log(Financial corporates loans)	1,674	17.69132	3.343819	0.6931472	24.55176
Log(Non-financial corporates loans)	2,730	18.36485	3.495803	4.067316	26.88868
Log(SME loans)	1,904	17.47616	3.525487	3.09603	24.34852
Log(Non-financial businesses loans)	3,239	18.285	3.52331	4.067316	26.90185
Log(Retail loans)	3,041	16.44084	3.821936	2.873565	25.7537
Log(Tot Securities exp)	4,466	20.13993	2.550332	6.726273	27.15941
Log(Derivatives exp)	2,918	16.90445	4.153779	2.70805	26.36517
Log(Repos exp)	1,107	20.6049	3.776	5.987004	26.13937
CDS spreads on 5Y subordinated debt (bps)	54,397	162.5631	125.1609	-1.32	1,775

Source: CDS spreads from Refinitiv Eikon; exposure data from Bank of England regulatory returns

5. Empirical design

5.1. Baseline DiD model

At its introduction, the leverage ratio was applicable only to a sub-group of banks. This provides a suitable setup for a DiD exercise. The DiD model allows us to compare the behaviour of LR banks to non-LR banks post the leverage ratio introduction, and hence test our theoretical predictions. Following Giansante et al. (2022), our main DiD regression is:

$$\log(Y_{i,t}) = \beta_i + \delta_1(Treated_i\ \boldsymbol{LR}) + \ \delta_2(Treated_i\ Cibls_i\ \boldsymbol{LR}) + \gamma_1\boldsymbol{LR} + \gamma_2\boldsymbol{LR}Cibls_i + \theta X_{i,t} + \varsigma(X_{i,t}\ \boldsymbol{LR}) + \ \upsilon_{i,t} \qquad (10)$$

where, $Y_{i,t}$: log of exposures (in different risk weight buckets, or of different types), average risk weight or the leverage ratio. β_i: bank fixed effect; $Treated_i$: treatment dummy, set to 1 for LR banks and 0 otherwise. LR: treatment time dummy, which is set to 0 before 2016 Q1 and 1 afterwards. $Cibls_i$: a dummy for The UK government's Coronavirus Business Interruption Lending Scheme (CIBLS)[11], which

[11] This dummy is only used for lending to non-financial businesses regressions shown in the Appendix.

is equal to 1 for banks participating in the scheme and 0 otherwise. $Treated_i \times \boldsymbol{LR}$: interaction of treatment and time dummies. $Treated_i \times Cibls_i \times \boldsymbol{LR}$: triple interaction of treatment, CIBLS and time dummies. $X_{i,t}$: a matrix of controls; $X_{i,t}\, LR$: interaction terms to control for heterogeneous responses due the nature of the banks. To allow for serial correlation over time, we use standard errors clustered at bank level. It is worth noting here that while only a few banks are subject to the leverage ratio capital requirements, all banks are subject to supervisory expectations of maintaining their capital position such that they meet minimum leverage ratio requirements. There are several differences between the actual requirements and expectations, such as the consequences of not holding sufficient capital and the applicability of leverage ratio buffers. We think that due to these differences, the validity of our results is not affected by the presence of leverage ratio expectations. It is also worth noting that our exercise abstracts from the effects of other policy and/or regulatory changes that happened after the introduction of the leverage ratio. This includes changes to the counter-cyclical capital buffers by the Bank of England's Financial Policy Committee or changes in the Globally Systemically Important Banks (GSIBs) buffer determined by the Financial Stability Board (which both reflect on leverage ratio buffer requirements), as well as the introduction of ring-fencing structural reforms. Our analysis does not attempt to assess the effects of the changes to the leverage such as the exemption of central bank exposures from the leverage ratio. Nevertheless, some of the robustness checks we present at the end of the empirical exercise can alleviate (at least partially) the effects of the above-mentioned changes. Lastly, the existence of two capital requirements (risk-weighted and leverage ratio) means some banks could be bound by either or both requirements, depending on the business model of the bank. Our results presented below would hold even when controlling for the binding-ness of the leverage ratio requirements.

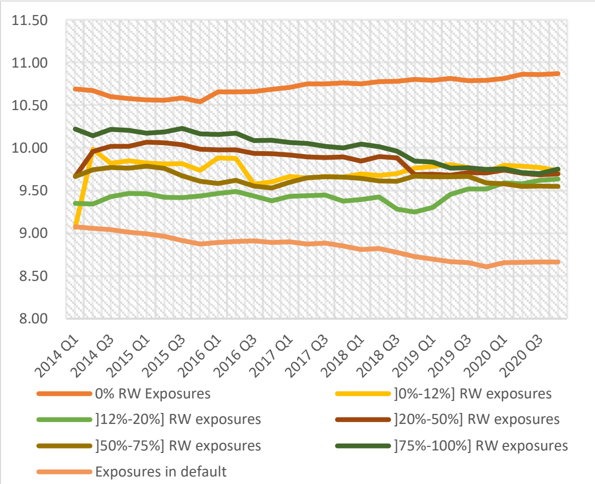
5.2. Propensity score matching

As mentioned earlier, the leverage ratio in the UK was applicable only to banks with retails deposits of £50 billion or more. Hence, the selection into the treatment group (i.e., LR banks) is not random, as it reflects certain bank characteristics, such as size and business model. LR banks are relatively bigger and have more diverse business models than non-LR banks. This makes our results prone to selection bias effects since differences in risk-taking behaviour could be driven by these bank characteristics rather than the treatment status.

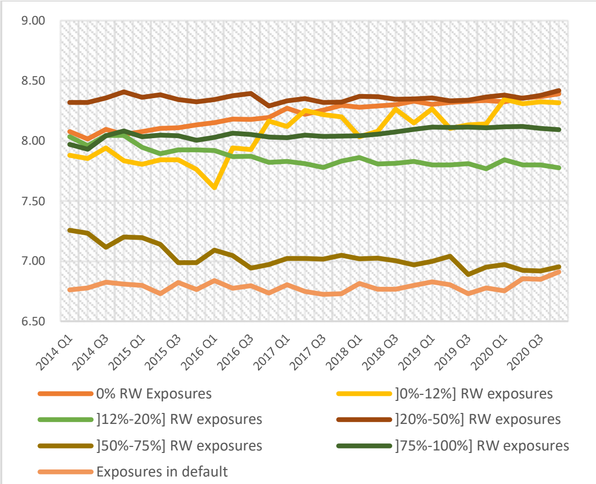
Figure 1: Average trends of LR-banks and non-LR-banks

Panel (a) – Exposures by risk weight buckets (in logs)

LR-banks

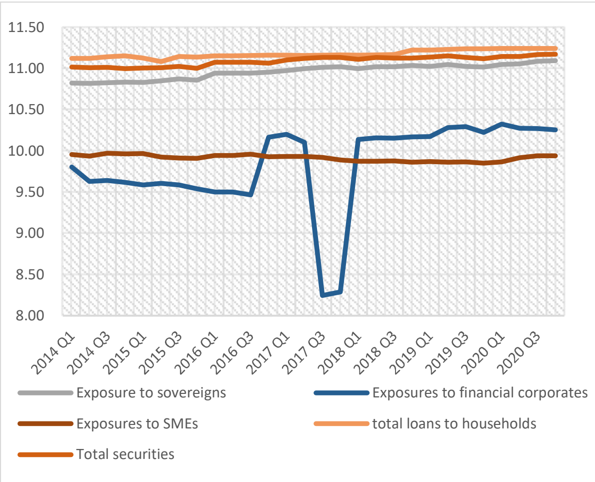


Non-LR-banks

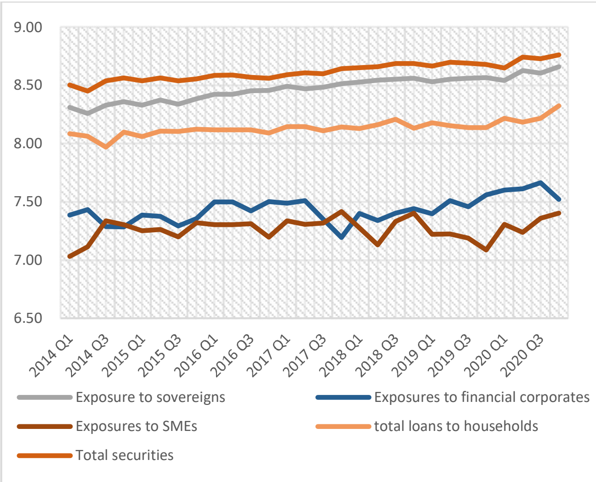


Panel (b) – Exposures by type of exposure (in logs)

LR-banks

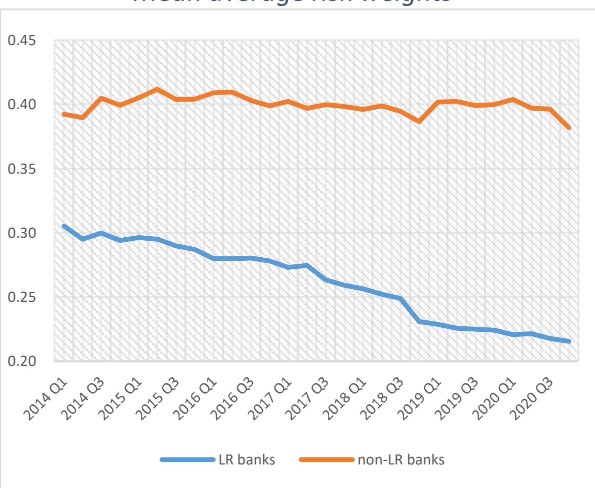


Non-LR-banks

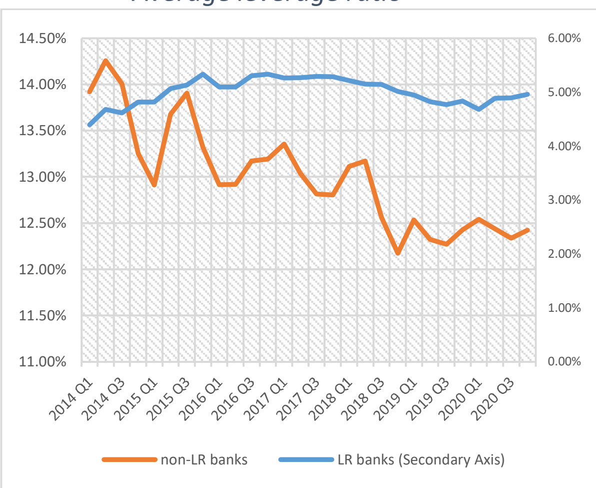


Panel (c) – Average risk weights and leverage ratios

Mean average risk weights



Average leverage ratio



Source: Bank of England regulatory returns

Indeed, as Figure 1 illustrates, there were some differences between LR banks and LR banks and non-LR before the introduction of the leverage ratio. For example, the trend of falling average risk weights and increasing leverage ratios (Panel (c)) of LR banks pre-dates the leverage ratio (and even started before our sample). As such, by implementing a DiD on the whole treatment and control groups, we may underestimate or overestimate the effects of leverage ratio. To address the potential selection bias and isolate the impact of leverage ratio, we use a propensity-score-matching to create a comparable control group for each treated bank, following Rodnyansky and Darmouni (2017) and Giansante et al (2022). We do the matching in three steps. First, we regress the treatment dummy on bank-level variables, reflecting size, business model, and capitalisation, to determine bank characteristics correlated with the treatment status. We then match each of the treated banks with most similar banks in the control group in terms of these characteristics. We use 1:5 matching ratio, where we match each treated bank with the most similar five banks in the control group.[12] We lastly, rerun the regressions in the first step on the matched sample, to check whether differences between the treatment and control groups disappear.

Table 2: Propensity Score Matching

	(1)	(2)
VARIABLES	*Treated*	
Size	1.374*** (0.273)	1.626 (1.449)
RWA	-0.387 (3.419)	15.972 (10.007)
Tier 1	0.040** (0.017)	7.183 (6.203)
Tot Securities	-2.758* (1.497)	-21.613 (21.910)
Off Balance Sheet exp.	4.820** (1.934)	18.836 (23.465)
Matching	-pre	-post
Adj. R-squared	0.863	0.553
p-value	0.000	0.002
N	151	42

Probit regressing the treatment on bank characteristics in 2015Q4. The dependent variable is the bank treatment status. The independent variables are size measured as the log of total leverage exposures, risk weighted assets over total leverage exposure, Tier 1 capital over risk weighted assets, total securities over total leverage exposure and off-balance sheet exposure over total leverage exposure. Model (1) reports the pre-matching results while model (2) reports the post matching results with a matching ratio of 1:5. Coefficients and standard errors are reported for each variable. Standard errors are clustered at the bank level and reported between parentheses, * p<0.10 ** p<0.05 *** p<0.01

[12] We try other matching ratios (from 1:1 to 1:8), and matching results are generally consistent. We opt for 1:5 matching ratio since it minimises post-matching differences between the treatment and control groups. The results of matching using other matching ratios are non-tabulated and available from the authors upon request.

Table 2 shows correlations between treatment status and size and business models of banks before and after matching, based on 2015 Q4 data (just before leverage ratio introduction). As the estimates in model (1) indicate, LR banks were bigger and had more securities and off-balance sheet exposures than non-LR banks. Post matching, average differences disappear, as model (2) suggest.

6. Results

6.1. Asset risk

Our earlier theoretical assessment suggests that introducing the leverage ratio into a regulatory regime with only risk-based capital requirements can induce banks to increase riskiness of their assets. To assess this insight empirically, we run the DiD model in Equation (10) for average risk weight, and exposures in different risk weight buckets, to investigate whether LR banks show any shift towards higher risk weight buckets and/or any increases in average risk weights, relative to the control group. Results are shown in Table 3. On average, the decomposition of total exposures by risk weight buckets of LR banks does not show statistically significant differences relative to non-LR banks. This suggests that compared to non-LR banks, LR banks did not shift towards assets in higher risk weight buckets following the leverage ratio introduction. Nevertheless, the negative coefficient on the average risk weight indicates that LR banks reduced their average risk weight by about 7 percentage points, in line with Figure 1 panel (c). These results indicate that LR banks did not increase asset risk, compared to non-LR banks. Results hold even if we exclude the COVID period (panel (b) of Table 3). We further support this assessment with a DiD model for different asset classes or exposure types (Appendix A4).

6.2. Insolvency risk

Our earlier theoretical model results indicate that the any shift from safer towards riskier assets would be less than 1-for-1, due to the higher risk weights riskier assets attract. As such, the introduction of leverage ratio requirements would lead to lower levels of leverage and insolvency risk. To assess effects on insolvency risk, we run the DiD model for the (regulatory) leverage ratio, defined as Tier 1 capital divided by total leverage ratio exposure measure, as discussed in Section 2. As such, a positive change (an increase) in the leverage ratio indicates lower level of leverage and lower insolvency risk. As Table 3 shows, LR banks increased their leverage ratios compared to non-LR banks by 6.2bps, on average. This increase is marginal, as it represents an increase of around 1-1.5% in the leverage ratios of LR-banks. This indicates a slight reduction in insolvency risk of LR banks, relative to non-LR banks.

Table 3: DiD results for leverage ratio, average risk weights and decomposition of exposures by risk weight buckets

Panel (a) including COVID period

VARIABLES	Leverage ratio	Average risk weight	0% RW exposures	]0%-12%] RW exposures	]12%-20%] RW exposures	]20%-50%] RW exposures	]50%-75%] RW exposures	]75%-100%] RW exposures	Exposures in default
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
*Treated * LR*	0.0621**	-0.0728	-1.686	3.581	2.215	-1.098	5.288	0.325	-3.504
	(0.0248)	(0.0530)	(2.778)	(4.074)	(1.719)	(0.930)	(4.183)	(0.246)	(5.133)
Observations	1,176	1,176	861	777	1,057	1,176	952	1,169	707
R-squared	0.680	0.616	0.167	0.592	0.688	0.860	0.453	0.969	0.719
LR	YES	YES	YES	YES	YES	YES	YES	YES	YES
Controls	YES	YES	YES	YES	YES	YES	YES	YES	YES
Controls * **LR**	YES	YES	YES	YES	YES	YES	YES	YES	YES
Bank FEs	YES	YES	YES	YES	YES	YES	YES	YES	YES

Panel (b) excluding COVID period

VARIABLES	Leverage ratio	Average risk weight	0% RW exposures	]0%-12%] RW exposures	]12%-20%] RW exposures	]20%-50%] RW exposures	]50%-75%] RW exposures	]75%-100%] RW exposures	Exposures in default
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
*Treated * LR*	0.0595***	-0.0846	-1.725	4.243	1.570	-1.442	3.881	0.303	-3.674
	(0.0183)	(0.0498)	(3.004)	(3.992)	(1.560)	(1.234)	(2.930)	(0.239)	(4.306)
Observations	1,008	1,008	735	665	889	1,008	812	1,001	567
R-squared	0.729	0.608	0.256	0.569	0.729	0.886	0.448	0.971	0.783
LR	YES	YES	YES	YES	YES	YES	YES	YES	YES
Controls	YES	YES	YES	YES	YES	YES	YES	YES	YES
Controls * **LR**	YES	YES	YES	YES	YES	YES	YES	YES	YES
Bank FEs	YES	YES	YES	YES	YES	YES	YES	YES	YES

Coefficient estimates of quarterly regulatory exposures of banks from 2014 Q1 to 2020 Q4 using a 1:5 matching ratio. Treatment status $Treated_i$ equals to 1 for LR banks and 0 for non LR-banks. LR equals to 1 from Jan 2016, and 0 before that. Controls are size measured as the log of total leverage exposure, Tier1 capital ratio, risk weighted assets, securities over total leverage exposure and off-balance sheet over total leverage exposure to control business models. Standard errors (in parentheses) are clustered at the bank level, * p<0.10 ** p<0.05 *** p<0.01.

6.3. Aggregate level of risk

With a stable asset risk and slightly falling insolvency risk, we expect aggregate level of risk of LR bank to fall slightly, or at least not increase, relative to non-LR banks. To assess this prediction, we run the DiD model for average CDS spreads on 5-year subordinated debt. Results in Table 4 suggest that CDS spreads of LR banks fell by 1.5pps (1.1pps, if COVID stress is excluded) compared to non-LR banks. Therefore, although LR led to a slight fall in the level of leverage, investors appear to have viewed LR banks more creditworthy/resilient, especially in stress.

Table 4: DiD results for CDS spreads on 5-year subordinated debt

CDS spreads on 5Y subordinated debt	Including Covid period (1)	Excluding Covid period (2)
*Treated * LR*	-150.0*** (19.12)	-110.3*** (17.87)
Observations	16,377	15,615
R-squared	0.471	0.529
LR	YES	YES
Controls	YES	YES
Controls * **LR**	YES	YES
Bank FEs	YES	YES

Coefficient estimates of daily CDS spreads on 5-year subordinated debt from 01 January 2014 to 31 December 2020. Treatment status $Treated_i$ equals to 1 for LR banks and 0 for non-LR banks. Controls are size measured as the log of total leverage exposure, Tier1 capital ratio, risk weighted assets, securities over total leverage exposure and off-balance sheet over total leverage exposure to control business models. Standard errors (in parentheses) are clustered at the bank level, * p<0.10 ** p<0.05 *** p<0.01.

7. Robustness tests

In this section, we present the robustness experiments we ran to ensure of our results. These includes rerunning the DiD models with artificial treatment timing, or using an alternative treatment group, to falsify the treatment timing and treatment status, respectively. In the third test, we also rerun our DiD models after dropping the COVID-19 period.

7.1. Timing effects

We do two separate experiments on timing of the treatment. In the first experiment, we drop the leverage ratio period from our sample completely (i.e., all observations from 2016 onwards). This leaves us with two years (eight quarters) of data. We create an artificial treatment at the middle of that period (end 2014) and rerun our three DiD regressions. In the second experiment, we keep the original dataset, but move the treatment timing from beginning of 2016 to the middle of the entire sample (i.e., start of July 2017), and rerun the DiD regressions. Results for both experiments are presented in Table 5. As the results suggest, in contrast with the baseline, the treatment effects for the leverage ratio (insolvency risk) disappear, and the treatment group starts to show some relative differences from the control group in terms of the decomposition of exposures by risk weight buckets. The CDS spreads of LR banks increase rather than decrease relative to control group (Panel (b)).

7.2. Using an alternative treatment group

In this experiment, we drop the LR banks from the sample, and generate an alternative treatment group that includes banks from the control group that are most matched with LR banks in the propensity score matching we carried out in the baseline analysis. We then compare the behaviour of this alternative treatment group to the rest of the control group. The rationale of this placebo test is as follows. The alternative treatment group includes banks most similar to the actual treatment group, which would most likely have been in the treatment group if the LR banks did not exist. As with the treatment timing experiments, treatment effects for the leverage ratio disappear, some differences appear in the decomposition of exposures by risk weight buckets, and CDS spreads of the (alternative) treatment group increase rather than decrease relative to control group.

7.3. Results excluding the COVID period

To ensure our results are not driven by the one-off event of COVID-19, we rerun our DiD models after dropping observations after 2019 Q4. Results for these regressions are displayed in Table 3 and Table 4, and are consistent with the results of the baseline regressions, but slightly smaller.

7.4. Dropping high yield-disequilibrium periods

At the end of the section covering our theoretical model (Section 3), we indicate that risk shifting would happen following the introduction of leverage ratio if the risk-adjusted capital-adjusted returns on the risky and safe assets do not indicate significant disequilibrium. We further illustrate this in Appendix A3. To empirically investigate whether our results would be different if the disequilibrium between safe and risky assets was lower, we use data on interest rates on SME lending and gilts yields to calculate representative risk-adjusted capital-adjusted returns for risky and safe assets.

Table 5: Robustness tests --- timing effects and treatment status

Panel (a) lending leverage ratio, average risk weights and decomposition of exposures by risk weight buckets

VARIABLES	Leverage ratio	Average risk weight	0% RW exposures	]0%-12%] RW exposures	]12%-20%] RW exposures	]20%-50%] RW exposures	]50%-75%] RW exposures	]75%-100%] RW exposures	Exposures in default
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Timing effects (EXP1) --- original treatment group, sample period 2014 Q1 to 2015 Q4, treatment at the start of 2015									
*Treated * LR*	-0.000087 (0.00495)	-0.0229 (0.0202)	-0.363* (0.173)	-0.318 (0.877)	0.817*** (0.169)	0.892 (0.803)	0.643 (0.485)	0.533 (0.314)	0.214 (0.680)
Observations	384	384	384	192	384	384	384	384	369
R-squared	0.921	0.634	0.983	0.648	0.903	0.769	0.909	0.971	0.783
Timing effects (EXP2) --- original treatment group, sample period 2014 Q1 to 2020 Q4, treatment in July 2017									
*Treated * LR*	-3.348 (2.181)	-21.04 (14.25)	0.540* (0.317)	-1.716** (0.712)	-0.302 (0.323)	0.0114 (0.247)	0.119 (0.387)	-0.00628 (0.203)	-0.279 (0.480)
Observations	3,784	3,784	3,662	1,322	3,705	3,567	2,567	3,687	2,494
R-squared	0.486	0.479	0.273	0.224	0.107	0.273	0.111	0.422	0.112
Treatment status --- an alternative treatment group, sample period 2014 Q1 to 2020 Q4, treatment at the start of 2016									
*Treated * LR*	-0.00743 (0.00593)	0.0530* (0.0391)	-0.724 (0.777)	2.852 (2.510)	0.430 (0.847)	-0.873 (0.852)	0.581 (2.064)	-0.649* (0.462)	5.593** (1.833)
Observations	840	840	715	623	808	835	603	824	503
R-squared	0.473	0.515	0.231	0.670	0.576	0.565	0.425	0.778	0.625
LR	YES	YES	YES	YES	YES	YES	YES	YES	YES
Controls	YES	YES	YES	YES	YES	YES	YES	YES	YES
Controls * **LR**	YES	YES	YES	YES	YES	YES	YES	YES	YES
Bank FEs	YES	YES	YES	YES	YES	YES	YES	YES	YES

Coefficient estimates of quarterly regulatory exposures of banks using a 1:5 matching ratio. Treatment status $Treated_i$ equals to 1 for treatment group banks and 0 otherwise. LR equals to 1 from treatment time, and 0 before that. Controls are size measured as the log of total leverage exposure, Tier1 capital ratio, risk weighted assets, securities over total leverage exposure and off-balance sheet over total leverage exposure to control business models. Standard errors (in parentheses) are clustered at the bank level, * p<0.10 ** p<0.05 *** p<0.01.

Panel (b) CDS spreads on 5-year subordinated debt

CDS spreads on 5Y subordinated debt	Timing effects (EXP1) (1)	Timing effects (EXP2) (2)	Treatment status (3)
*Treated * LR*	609.1*** (65.67)	37.62*** (10.35)	50.91*** (8.846)
Observations	4,698	16,377	19,241
R-squared	0.717	0.634	0.516
LR	YES	YES	YES
Controls	YES	YES	YES
Controls * **LR**	YES	YES	YES
Bank FEs	YES	YES	YES

Timing effects (EXP1): original treatment group, sample period 2014 Q1 to 2015 Q4, treatment at the start of 2015. Timing effects (EXP2): original treatment group, sample period 2014 Q1 to 2020 Q4, treatment in July 2017. Treatment status: an alternative treatment group, sample period 2014 Q1 to 2020 Q4, treatment at the start of 2016. Coefficient estimates of daily CDS spreads on 5-year subordinated debt. Treatment status $Treated_i$ equals to 1 for treatment group banks and 0 otherwise. LR equals to 1 from treatment time, and 0 before that. Controls are size measured as the log of total leverage exposure, Tier1 capital ratio, risk weighted assets, securities over total leverage exposure and off-balance sheet over total leverage exposure to control business models. Standard errors (in parentheses) are clustered at the bank level, * p<0.10 ** p<0.05 *** p<0.01.

We use these returns to estimate the level of disequilibrium in each quarter post the introduction of leverage ratio, and rank quarters in terms of the level of disequilibrium (difference between risk-adjusted capital adjusted returns on SME lending and gilts). We then rerun our baseline regressions after dropping quarters with the largest 50% disequilibrium levels. The results of DiD regressions for this experiment are presented in Table 6, and are consistent with the baseline results.

7.5. Using a shorter event window

Instead of using the whole sample, in this experiment we rerun our baseline models using a shorter event window. Particularly, we truncate our sample at the end of 2017, creating a four-year event window around the introduction of leverage ratio (2 years before and after). Results of this test are presented in Table 7, and are in line with the baseline results.

7.6. Dropping controls

The existence of time-varying control variables may contaminate DiD estimations (Atanasov and Black, 2016). We mitigate this concern by re-running our baseline estimations without any bank-level controls. As Table 8 shows, our baseline results hold even when the time varying controls are excluded.

Table 6: Robustness tests --- DiD results based on periods with lowes disequilibrium between returns on SME lending and gilts

Panel (a) lending leverage ratio, average risk weights and decomposition of exposures by risk weight buckets

VARIABLES	Leverage ratio	Average risk weight	0% RW exposures	]0%-12%] RW exposures	]12%-20%] RW exposures	]20%-50%] RW exposures	]50%-75%] RW exposures	]75%-100%] RW exposures	Exposures in default
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
*Treated * LR*	0.0591** (0.0231)	0.203 (0.9918)	6.948 (5.046)	3.236 (3.783)	1.948 (1.795)	-1.789 (1.809)	-0.388 (3.480)	0.916 (1.374)	-4.662 (6.898)
Observations	756	756	546	497	693	756	602	756	469
R-squared	0.737	0.792	0.271	0.549	0.739	0.897	0.697	0.977	0.737
LR	YES	YES	YES	YES	YES	YES	YES	YES	YES
Controls	YES	YES	YES	YES	YES	YES	YES	YES	YES
Controls * **LR**	YES	YES	YES	YES	YES	YES	YES	YES	YES
Bank FEs	YES	YES	YES	YES	YES	YES	YES	YES	YES

Coefficient estimates of quarterly regulatory exposures of banks from 2014 Q1 to 2020 Q4, excl. high disequilibrium quarters. Treatment status $Treated_i$ equals to 1 for LR banks and 0 for non LR-banks. LR equals to 1 from Jan 2016, and 0 before that. Controls are size measured as the log of total leverage exposure, Tier1 capital ratio, risk weighted assets, securities over total leverage exposure and off-balance sheet over total leverage exposure to control business models. Standard errors (in parentheses) are clustered at the bank level, * p<0.10 ** p<0.05 *** p<0.01.

Panel (b) CDS spreads on 5-year subordinated debt

	CDS spreads on 5Y subordinated debt
*Treated * LR*	-228.6*** (19.48)
Observations	10,540
R-squared	0.518
LR	YES
Controls	YES
Controls * **LR**	YES
Bank FEs	YES

Coefficient estimates of daily CDS spreads on 5-year subordinated debt from 01 January 2014 to 31 December 2020, excl. high disequilibrium quarters. Treatment status $Treated_i$ equals to 1 for LR banks and 0 for non-LR banks. Controls are size measured as the log of total leverage exposure, Tier1 capital ratio, risk weighted assets, securities over total leverage exposure and off-balance sheet over total leverage exposure to control business models. Standard errors (in parentheses) are clustered at the bank level, * p<0.10 ** p<0.05 *** p<0.01.

Table 7: Robustness tests --- Shorter even window (2 years before and after LR introduction)

Panel (a) lending leverage ratio, average risk weights and decomposition of exposures by risk weight buckets

VARIABLES	Leverage ratio (1)	Average risk weight (2)	0% RW exposures (3)	]0%-12%] RW exposures (4)	]12%-20%] RW exposures (5)	]20%-50%] RW exposures (6)	]50%-75%] RW exposures (7)	]75%-100%] RW exposures (8)	Exposures in default (9)
*Treated * LR*	0.0645*** (0.0157)	-0.0688 (0.0514)	2.083 (1.930)	4.571 (3.870)	1.266 (0.923)	-1.300 (1.087)	2.953 (2.427)	0.347 (0.245)	-2.692 (2.858)
Observations	840	840	609	553	721	840	686	833	455
R-squared	0.738	0.535	0.606	0.544	0.768	0.932	0.582	0.975	0.828
LR	YES	YES	YES	YES	YES	YES	YES	YES	YES
Controls	YES	YES	YES	YES	YES	YES	YES	YES	YES
Controls * **LR**	YES	YES	YES	YES	YES	YES	YES	YES	YES
Bank FEs	YES	YES	YES	YES	YES	YES	YES	YES	YES

Coefficient estimates of quarterly regulatory exposures of banks from 2014 Q1 to 2017 Q4 using a 1:5 matching ratio. Treatment status $Treated_i$ equals to 1 for LR banks and 0 for non LR-banks. LR equals to 1 from Jan 2016, and 0 before that. Controls are size measured as the log of total leverage exposure, Tier1 capital ratio, risk weighted assets, securities over total leverage exposure and off-balance sheet over total leverage exposure to control business models. Standard errors (in parentheses) are clustered at the bank level, * p<0.10 ** p<0.05 *** p<0.01.

Panel (b) CDS spreads on 5-year subordinated debt

CDS spreads on 5Y subordinated debt	
*Treated * LR*	-272.4*** (18.75)
Observations	11,702
R-squared	0.582
Controls	YES
Controls * **LR**	YES
LR	YES
Bank FEs	YES

Coefficient estimates of daily CDS spreads on 5-year subordinated debt from 01 January 2014 to 31 December 2017. Treatment status $Treated_i$ equals to 1 for LR banks and 0 for non-LR banks. Controls are size measured as the log of total leverage exposure, Tier1 capital ratio, risk weighted assets, securities over total leverage exposure and off-balance sheet over total leverage exposure to control business models. Standard errors (in parentheses) are clustered at the bank level, * p<0.10 ** p<0.05 *** p<0.01.

Table 8: Robustness tests --- no time varying bank-level controls

Panel (a) lending leverage ratio, average risk weights and decomposition of exposures by risk weight buckets

VARIABLES	Leverage ratio	Average risk weight	0% RW exposures	]0%-12%] RW exposures	]12%-20%] RW exposures	]20%-50%] RW exposures	]50%-75%] RW exposures	]75%-100%] RW exposures	Exposures in default
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
*Treated * LR*	0.0246*** (0.00232)	-0.0961 (0.0424)	0.188 (0.885)	-2.870 (3.433)	-0.920 (0.668)	1.156 (1.700)	-0.0692 (0.986)	0.701 (1.180)	-2.255 (1.527)
Observations	1,176	1,176	861	777	1,057	1,176	952	1,169	707
R-squared	0.135	0.072	0.003	0.346	0.158	0.062	0.000	0.063	0.193
LR	YES	YES	YES	YES	YES	YES	YES	YES	YES
Bank FEs	YES	YES	YES	YES	YES	YES	YES	YES	YES

Coefficient estimates of average pre and post treatment regulatory exposures of banks from 2014 Q1 to 2020 Q4 using a 1:5 matching ratio. Treatment status $Treated_i$ equals to 1 for LR banks and 0 for non LR-banks. LR equals to 1 from Jan 2016, and 0 before that. Standard errors (in parentheses) are clustered at the bank level, * p<0.10 ** p<0.05 *** p<0.01.

Panel (b) CDS spreads on 5-year subordinated debt

	CDS spreads on 5Y subordinated debt
*Treated * LR*	-71.63*** (1.927)
Observations	54,399
R-squared	0.047
LR	YES
Bank FEs	YES

Coefficient estimates of average pre and post treatment CDS spreads on 5-year subordinated debt from 2014 to 2020. Treatment status $Treated_i$ equals to 1 for LR banks and 0 for non-LR banks. Standard errors (in parentheses) are clustered at the bank level, * p<0.10 ** p<0.05 *** p<0.01.

8. Conclusion

The leverage ratio was introduced as part of the post 2007-08 financial crisis Basel reforms as a simple measure, complementing the risk-based capital requirements for banks. The leverage ratio captures both on-balance sheet and off-balance sheet exposures of banks in a risk-neutral fashion, without applying risk weights reflecting the riskiness of exposures, as in the risk-based capital requirements. Consequently, introducing the ratio into a regulatory regime with risk-based requirements only sets a floor for risk weights. The floor would be binding for the low-risk activities with low-risk weights (for example, repo lending), and hence may prompt a shift towards riskier assets. Yet, due to higher risk weights on riskier assets, the increase in asset-risk would be accompanied with a lower level of leverage and insolvency risk. Thus, the impact on the aggregate level of risk relies on the interaction of these two forces.

In this paper, we assessed the impact of leverage ratio capital requirements on risk-taking behaviour of banks theoretically, using a simple stylised model, and empirically. When introduced in the UK in 2016, the leverage ratio was only applicable to a subgroup of banks, allowing for a difference-in-difference (DiD) setup, in which we compare the risk-taking behaviour of banks subject to the leverage ratio (LR banks) relative to similar banks not subject to it (non-LR banks). Our theoretical model suggested that binding leverage ratio requirements could induce a shift towards riskier assets (i.e., higher asset risk), when introduced into a risk-based only regulatory regime. However, this shift would not be one-for-one, due to the higher risk weights the riskier assets attract, making the bank less leveraged (i.e., lower insolvency risk). Our empirical results indicate that LR banks did not increase asset risk, and slightly reduced leverage levels, compared to the control group after the introduction of leverage ratio in the UK. As expected, these two changes led to a lower aggregate level of risk. The DiD results show that credit default swap (CDS) spreads on 5-year subordinated debt of LR banks fell relative to non-LR banks post leverage ratio introduction, suggesting the market viewed LR banks as less risky, especially during COVID stress.

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Appendix

A1. Variable Definitions

- **Treated** – Dummy variable that equals to 1 for LR-banks and 0 for non-LR-banks
- **Size** – log of total leverage ratio exposures
- **Risk weighted assets (RWAs)** – log of risk weighted assets
- **Leverage ratio** – Tier 1 capital divided by total leverage ratio exposures
- **Average risk weight** – risk weighted assets divided by total leverage ratio exposures
- **Exposures in different risk weight buckets** – total exposures in different risk weight buckets according to European Capital Requirements Regulation (CRR)
- **SME Loans** – exposures to SMEs according to European Capital Requirements Regulation (CRR)
- **Non-Financial Corporate (NFC) Loans** – exposures to non-financial corporates other than SME
- **Total Non-Financial Business (NFB) Loans –** exposures to SMEs and nonfinancial corporates
- **Retail Loans** – retail exposures as defined in CRR
- **Financial Corporate Loans** – total exposures to financial corporates as defined in CRR
- **Sovereign Exposures** – exposures to sovereigns as defined in CRR
- **Total Securities** – some of exposures to sovereigns and other securities exposures
- **Derivative Exposures** – derivatives leverage ratio exposures as defined in CRR
- **SFTs Exposures** – securities financing transactions leverage ratio exposures as defined in CRR
- **Off-balance sheet exposures** – off-balance sheet leverage ratio exposures as defined in CRR
- **Tier 1 capital ratio –** Tier 1 capital divided by risk weighted assets
- **Deposits** – Customer deposit current + customer deposit savings + customer deposits term

A2. Unit-level application of regulatory requirements

When it was introduced, the leverage ratio was applicable at the level of the banking group, rather than individual solo entities or business units. As such, both requirements in our model apply to the bank as one unit (bank-level). Yet, the bank's internal procedures ultimately determine the level at which the requirements apply. The bank may choose to apply the requirements at the bank-level, or at the unit-level (i.e., to individual business units). In the first case, capital is fungible across business lines, whereas in the second the bank endows each line with a specific amount of capital. There is evidence that some banks follow a benchmarking approach to allocate capital to their business units, under which they consider the leverage ratio capital requirements of each unit (for example, Bank of England, 2018). In our theoretical model, if the bank chose to apply the requirements at the business unit-level, endows each of the two business lines (gilts and lending) with a specific amount of capital (E_S and E_L). The risk-based and leverage ratio constraints in Equations (2) and (3) become:

$$\frac{E_S}{w_s S} \geq \chi_1 \tag{11}$$

$$\frac{E_L}{w_L L} \geq \chi_1 \tag{12}$$

$$\frac{E_S}{S} \geq \chi_2 \tag{13}$$

$$\frac{E_L}{\mathrm{L}} \geq \chi_2 \tag{14}$$

The bank problem is expressed by Equations (1), (11) and (12) pre-LR, and Equations (1), (12) and (13) post-LR. Constraints in Equations (11) and (14) are redundant, as gilts are bound by the leverage ratio, whereas loans are bound by the risk-based requirements. The optimal values pre and post LR are:

$$S^*_{Pre-LR} = \frac{\frac{1}{w_s\chi_1} r_s - \frac{1}{w_L\chi_1} r_L + 2\delta_L \frac{E}{w_L\chi_1}}{2w_s\left(\frac{1}{w_s}\delta_S + \frac{1}{w_L}\delta_L\right)} \tag{15}$$

$$L^*_{Pre-LR} = \frac{\frac{1}{w_L\chi_1} r_L - \frac{1}{w_s\chi_1} r_s + 2\delta_S \frac{E}{w_S\chi_1}}{2w_L\left(\frac{1}{w_s}\delta_S + \frac{1}{w_L}\delta_L\right)} \tag{16}$$

$$S^*_{Post-LR} = \frac{\frac{1}{\chi_2} r_s - \frac{1}{w_L\chi_1} r_L + 2\delta_L \frac{E}{w_L\chi_1}}{2\chi_2\left(\frac{1}{\chi_2}\delta_S + \frac{1}{w_L\chi_1}\delta_L\right)} \tag{17}$$

$$L^*_{Post-LR} = \frac{\frac{1}{w_L\chi_1} r_L - \frac{1}{\chi_2} r_s + 2\delta_S \frac{E}{\chi_2}}{2w_L\chi_1\left(\frac{1}{\chi_2}\delta_S + \frac{1}{w_L\chi_1}\delta_L\right)} \tag{18}$$

As with the bank-level application of requirements, while the optimal allocation shifts towards less gilts and more loans, total assets fall, implying lower level of leverage.

A3. Low yield environment and impact of LR on asset risk

To illustrate our point, we will use a stylised example of a bank with two assets 10Y gilts, whose risk weight is 5% (safe asset), and loans to small and medium enterprises (SMEs), with risk weight of 75% (risky asset). We set the risk-based requirements at 12% and leverage ratio requirements at 3%. In January 2016 (when the leverage ratio was introduced), the average interest rate on new SME loans was 3.34% (2.25% on risk-adjusted basis), whereas the average yield on 10Y gilts was 1.78%. Given the risk weights, the amount of equity needed to support £1 increase in SME loans would be 15x that needed for the same investment in gilts ($E_l = 0.09$ vs $E_s = 0.006$). Hence, as Equation (9 implies, pre leverage ratio ROEs would be 297% for gilts compared to 25% for SMEs (37.1%, on gross non-risk-adjusted basis). Post leverage ratio introduction, E_s increases to 0.03, reducing ROE on gilts to 59.3%. Since it is still higher than that for SME loans, the bank has no incentive to change its asset allocation. In fact, this would be the case unless the spread between the yields on the two assets expands (at the time, the spread was shrinking) or the effective risk weights of the two assets before leverage ratio introduction was closer. For example, if the risk weight on SME lending was 30% (i.e., ROE was 62.5%), then some risk shifting could happen.

A4. DiD results for Lending and other exposures

We assess here whether the decomposition of total exposures of LR banks across different asset classes or exposure types demonstrated any differences from that of non-LR banks post leverage ratio introduction. We run the DiD model for total mortgages, loans to households, loans to nonfinancial businesses, loans to banks and loans to financial corporations as well as exposures to sovereign, securities, derivatives, security financing transactions (repos), and off-balance sheet exposures. The DiD results listed in Table 9Table 9 indicate that LR banks reduced their exposures to SMEs compared to the control group after the introduction of leverage ratio. The growth of LR banks' SME exposures was about 93% less than non-LR banks. This decrease persists even after controlling for the effects of UK government COVID lending support schemes. Similarly, LR banks' exposures to financial corporates fell relative to non-LR banks by about 75% during the same period. Meanwhile, sovereign exposures of the treatment group grew by about 184% more than non-LR banks.

Table 9: DiD results for exposures by type

Panel (a) lending

VARIABLES	HHs loans	Mortgages	SME loans		NFC loans		NFB loans		Exposures to banks	FC loans
	(1)	(2)	(3a)	(3b)	(4a)	(4b)	(5a)	(5b)	(6)	(7)
*Treated * LR*	1.206	1.124	**-14.26****	**-14.33****	-3.745	-4.617	-1.283	-1.685	-1.009	**-4.020*****
	(2.596)	(2.580)	(4.689)	(4.815)	(6.148)	(6.172)	(4.162)	(4.167)	(1.637)	(0.700)
Observations	567	588	553	553	1,057	1,057	1,057	1,057	980	879
R-squared	0.553	0.547	0.424	0.424	0.566	0.569	0.639	0.643	0.421	0.793
LR	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
LR * CBILS	No	No	No	YES	No	YES	No	YES	No	No
Controls	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Controls * **LR**	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Bank FEs	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES

Panel (b) other exposures

VARIABLES	Sovereign exposures	Total securities	Off-balance sheet exposures	Derivatives exposures	SFT exposures
	(8)	(9)	(10)	(11)	(12)
*Treated * LR*	**1.836***	0.400	-0.468	-3.036	1.135
	(1.014)	(0.303)	(0.800)	(1.786)	(1.020)
Observations	833	1,176	980	910	942
R-squared	0.715	0.988	0.889	0.400	0.673
LR	YES	YES	YES	YES	YES
Controls	YES	YES	YES	YES	YES
Controls * **LR**	YES	YES	YES	YES	YES
Bank FEs	YES	YES	YES	YES	YES

Coefficient estimates of quarterly regulatory exposures of banks from 2014Q1 to 2020Q4 using a 1:5 matching ratio. Treatment status $Treated_i$ equals to 1 for LR-banks and 0 for non-LR-banks. Controls are size measured as the log of total leverage exposure, Tier1 ratio, risk weighted assets, securities over total leverage exposure and off-balance sheet over total leverage exposure to control for the business models of the banks. Standard errors are clustered at the bank level and reported between parentheses, * p<0.10 ** p<0.05 *** p<0.01.