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Leverage ratio, risk-based capital requirements, and risk-taking in the United Kingdom

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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. Conceptually, introducing binding leverage ratio requirements into a regulatory framework with risk-based capital requirements induces banks to re-optimise, 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 use a difference-in-differences setup to compare the behaviour of UK banks subject to the leverage ratio requirements (LR banks) to otherwise similar banks (non-LR banks). Our results 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 led to a lower aggregate level of risk. Emperical results indicate that credit default swap spreads on the 5-year subordinated debt of LR banks decreased relative to non-LR banks post leverage ratio introduction, suggesting the market viewed LR banks as less risky, especially during the COVID 19 stress.

KEYWORDS
capital regulation, finance, leverage ratio, risk-based requirements, risk-taking

JEL CLASSIFICATION
G01, G21, G28

1 | INTRODUCTION

In the years leading to the 2007–2008 great financial crisis (GFC), households, companies, banks and even governments borrowed intensively, leading to unprecedented levels of leverage. This was driven by factors such as financial innovation (e.g., securitisation) and falling real interest rates in major economies. These factors increased affordability, facilitated access to debt and reduced credit standards. When the crisis hit, several major banks, such as Lehman Brothers, were highly leveraged. Given their unique position in the system, the high leverage of banks has contributed significantly to the propagation of the crisis effects. Following the 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 the measurement of risk, address excessive leverage and liquidity risk, mitigate systemic risk, and improve bank supervision and market discipline (Basel Committee on Banking Supervision (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).[1] The leverage ratio was a part of the new capital measures introduced in 2010. 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 (e.g., 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,[2] and (iv) securities financing transaction exposures (SFTs), such as repo and repo-like transactions. Therefore, both on-balance sheet and off-balance sheet exposures of banks are captured by the leverage ratio in risk-neutral fashion, without applying risk weights, as opposed to the risk-based capital requirements. 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 (BCBS, 2014) and reduce the risk of bank runs (Dermine, 2015).

When introduced into a regulatory regime with only risk-based requirements, the leverage ratio imposes a de facto floor risk weight for all exposures. This floor would be binding for the low-risk activities with low-risk weights (e.g., 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 small businesses). 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 by a lower level of leverage (i.e., lower insolvency risk). 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.

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[3] or more in retail deposits[4]. 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. Since the leverage ratio was only applicable to a subgroup of banks, its implementation 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 risk-based capital requirements only. 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). We assess the effects of the leverage ratio on asset risk and insolvency risk by comparing the composition of assets in terms of riskiness and level of leverage of LR banks to those of non-LR banks. To assess the effects on the aggregate level of risk, we track the movements in credit defaul swaps (CDS) spreads of LR banks relative to non-LR banks after the leverage ratio introduction.

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 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.[5] Nevertheless, this risk shifting would only happen if the returns of the riskier assets are 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 or will not happen entirely. Such scenario is more likely to materialise in a low-yield environment, like that after 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. These two changes led to a lower aggregate level of risk. The DiD results show that CDS spreads of LR banks fell substantially relative to non-LR banks post leverage ratio introduction, suggesting the market viewed LR banks as less risky, especially in stress.

The remainder of the paper is as follows. Section 2 discusses the relevant literature on the leverage ratio 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 describe the robustness checks we employed. Section 8 concludes.

2 | RELATED LITERATURE

The risk-based capital requirements came into the scene in the 1980s in an attempt to prevent falls in bank capital positions like those witnessed in the 1970s (Jacques & Nigro, 1997). These requirements were emphasised by Basel standards in 1988, and then supplemented by approaches that aim to improve risk management incentives for banks in Basel II framework in 2004 (Leeladhar, 2007). While some earlier studies assess the impact of regulation on bank capital positions (e.g., Ediz et al., 1998; Rime, 2001), many focus on the effects of regulations on bank behaviour, especially risk-taking incentives. Most authors suggest that banking regulation generally reduce risk-taking of banks (for instance, Bolt & Tieman, 2004; Godlewski, 2005; Rime, 2001; and Rochet, 1992). However, this effect is largely determined by several factors such as competition (González, 2005), bank market power (Agoraki et al., 2011), bank (ex-ante) riskiness (Klomp & De Haan, 2012), and corporate governance structure (Laeven & Levine, 2009). Some studies have attempted to assess the effects of certain parts of the banking regulatory regime on risk-taking incentives, such as composition of bank regulatory capital (Fatouh & McCunn, 2022; and Martynova & Perotti, 2018), liquidity requirements (Roulet, 2018), and interactions between liquidity and capital requirements (Acosta-Smith, 2019). We contribute this strand of the literature by assessing the risk-taking implications of the leverage ratio as a main component of the post crisis reforms.

Prior to the introduction of the leverage ratio, the regulatory regime was primarily dominated by the risk-weighted capital requirements, which induced banks (especially under-capitalised banks) to restructure their assets towards low-risk activities which carry low risk weights such as sovereign bonds (Acharya & Steffen, 2015; and Fatouh et al., 2021). As such, there is a growing literature assessing the impact of the leverage ratio on bank behaviour (e.g., Acosta-Smith, Grill et al., 2020; and Neamtu & Vo, 2021), and especially bank provision of low-risk activities. Earlier studies (for instance, Baranova et al., 2017; Bicu-Lieb et al., 2020; Cenedese et al., 2021; Kotidis & Van Horen, 2018; and Noss &

Patel, 2019) suggest that the leverage ratio can affect banks' incentives to engage in low-risk activities. However, more recent analyses (e.g., Fatouh et al., 2021; Fatouh et al., 2022; and Gerba & Katsoulis, 2021) indicate that the effects of leverage ratio are confined to the pricing rather than the amounts of low-risk funding banks provide in the gilt repo market. Fatouh et al. (2022) 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 change 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. We add to this literature not only by assessing the risk-taking implications of the leverage ratio, but also its effects on the composition of banks asset mix.

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.

$$\pi = r_S S + r_L L - [\delta_S(S)]S - [\delta_L(L)]L \tag{1}$$

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 is subject to risk-based capital requirements set at χ_1 as follows, where w_i is the risk-weight allocated to asset *i* ($w_L > w_S$):

$$\frac{E}{w_s S + w_L L} \geq \chi_1 \tag{2}$$

However, the regulator recently introduced the following leverage ratio requirements set at χ_2:

$$\frac{E}{S + L} \geq \chi_2 \tag{3}$$

We assess the impact of leverage ratio introduction on the optimal allocation between gilts and loans. Since the leverage ratio is 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.[6] 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, S^*_{pre} and L^*_{pre}, respectively, are:

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

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

When the leverage ratio is introduced, the bank would be bound by either the risk-based or leverage ratio requirements.[7] In the first case, Equation (3) 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 post LR, S^*_{post} and

L^*_{post}, become:

$$S^*_{post} = \frac{r_s - r_L + 2\delta_L \frac{E}{\chi_2}}{2\left(\delta_S + \delta_L\right)} \tag{6}$$

$$L^*_{post} = \frac{r_L - r_S + 2\delta_S \frac{E}{\chi_2}}{2\left(\delta_S + \delta_L\right)} \tag{7}$$

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. That is, for a constant level of capital, any risk shifting creates two effects pulling on opposite directions on the aggregate level of risk of the bank, and the net impact depends on the balance of these two forces. The aggregate level of risk can be measured by the weighted average probability of default $\bar{D}$ on the two assets:

$$\bar{D} = \delta_S\left(S\right)\frac{S}{S+L} + \delta_L(L)\frac{L}{S+L} \tag{8}$$

If the weighted average probability of default post leverage ratio introduction, $\bar{D}_{post}$, is lower than that before it, $\bar{D}_{pre}$, 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.

3.2 | Leverage ratio and asset-risk a further look

The predictions above (higher asset risk and lower leverage) after leverage ratio introduction are based on the assumption 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 return on equity, ROE, of an additional £1 of an asset) on the two assets to be similar. That is:

$$\frac{r_s - \delta_S S}{E_S} = \frac{r_L - \delta_S L}{E_L} \tag{9}$$

If market conditions mean 9 that the left-hand side (LHS) of the Equation (9) is considerably higher than the right-hand side (RHS), the risk shifting will likely be limited. 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 post GFC up until the second half of 2021, during which the leverage ratio was introduced.[8]

4 | DATA

Our sample includes 173 UK banking groups, eight of which were subject to the leverage ratio.[9] Our dataset runs from January 2014 to December 2020 on quarterly basis, and comes from two main sources, Bank of Eng-

TABLE 1 Descriptive statistics on the data

Variables	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	.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 Refinitive Eikon; exposure data from Bank of England regulatory returns.

land'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. In line with the reporting requirements, these regulatory returns include information for all banks at different levels of consolidation. We focus on consolidated group data, as the leverage ratio requirements at inception applied at the group consolidation level[10]. Hence, although the leverage treatment of on-balance sheet exposures is generally based on the accounting treatment, our analysis would not be contaminated by the effects of intra-group exposures, which are dropped with the consolidation of accounts of different subsidiaries of a group. More specifically, if our assessment was carried out at the level of banking entities, our assessment could be largely affected by exposures between different entities of the same group. We use regulatory 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 provides an overview of our dataset.

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:

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

where, $Y_{i,t}$: log of exposures (in different risk weight buckets, or of different types), average risk weight, actual leverage ratio, or CDS spreads. 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 is equal to 1 for banks participating in the scheme and 0 otherwise. $Treated_i \times LR$: interaction of treatment and time dummies. $Treated_i \times Cibls_i \times LR$: triple interaction of treatment, CIBLS and time dummies. $X_{i,t}$: a matrix of controls; $X_{i,t}\, LR$: interaction variables 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.

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. 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 framework (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 the leverage ratio.

To address the potential selection bias and isolate the impact of the 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 the 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] Lastly, we rerun the regressions in the first step on the matched sample, to check whether differences between the treatment and control groups disappear.

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 between the treatment and control groups vanish, as model (2) suggest.

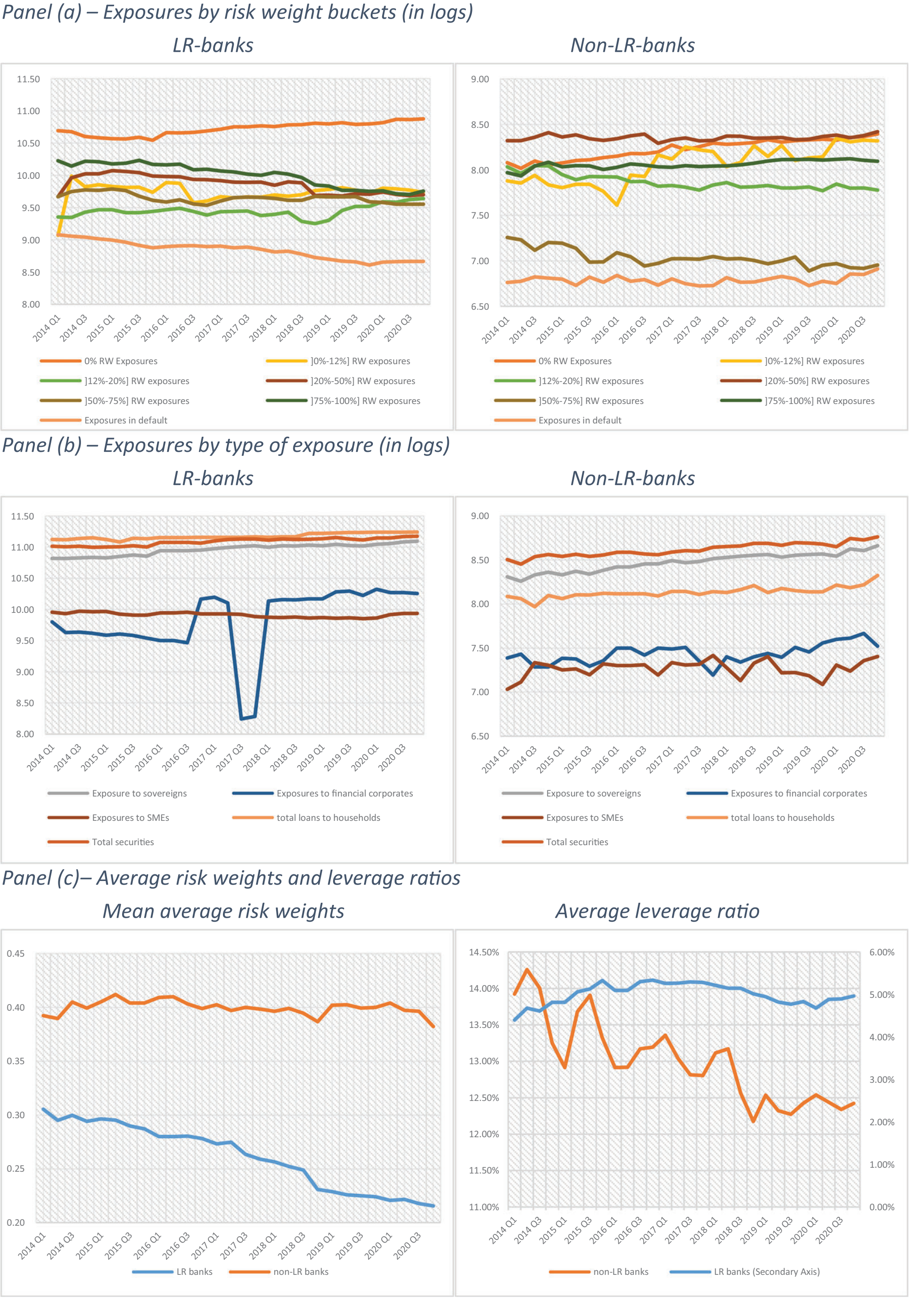

FIGURE 1 Average trends of LR-banks and non-LR-banks. LR, leverage ratio. [Color figure can be viewed at wileyonlinelibrary.com]

TABLE 2 Propensity score matching

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

Note: 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.

*$p < 0.10$.

**$p < 0.05$.

***$p < 0.01$.

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 may 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 gives an indication that LR banks reduced their average risk weight by about 7 percentage points, in line with Figure 1 panel (c). This suggests 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 also further support this assessment by running the DiD model for different asset classes or exposure types. The results of these regressions are in Appendix A4.

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 (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*	0.0621**	−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

(Continues)

TABLE 3 (Continued)

Panel (b) excluding COVID period									
	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
Variables	(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

Note: 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.

Abbreviation: LR, leverage ratio.

$^{*}p < 0.10$.
$^{**}p < 0.05$.
$^{***}p < 0.01$.

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***	−110.3***
	(19.12)	(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

Note: Coefficient estimates of daily CDS spreads on 5-year subordinated debt from 1 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.
Abbreviation: LR, leverage ratio.
*$p < 0.10$.
**$p < 0.05$.
***$p < 0.01$.

6.2 | Insolvency risk

Our theoretical model results indicate that 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 such, a positive change (an increase) in the leverage ratio reflects lower level of leverage and lower insolvency risk. As results in Table 3 show, LR banks increased their leverage ratios compared to non-LR banks by 6.2 bps, on average. In terms of magnitude, this increase resembles only a marginal improvement in the solvency of LR banks, as it represents around 1%–1.5% rise in the leverage ratios of LR banks. This indicates a slight reduction in insolvency risk of LR banks, relative to the control group. This is not unexpectable given that LR banks did not increase their asset risk as shown above. We think that these increases are driven by banks desire to disclose strong capital positions to the market and meet other requirements that changed with the introduction of leverage ratio such as stress-testing.

6.3 | Aggregate level of risk

The effects on the aggregate level of risk in our theoretical exercise rely on the interaction between the increase in asset risk and the fall in insolvency risk. With a stable asset risk and slightly falling insolvency risk, as the two sections above show, we expect the aggregate level of risk of LR bank to fall, 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 1.5 pps (1.1 pps if COVID stress is excluded) compared to non-

LR banks. This effect is significant in terms of magnitude, as it is an equivalent to more than 92% (67% when excluding COVID stress) of the average CDS spread in our sample (Table 1). Therefore, although the leverage ratio led to a slight fall in the level of leverage, investors appear to have viewed LR banks more creditworthy and resilient, especially in stress.

7 | ROBUSTNESS TESTS

In this section, we present the experiments we ran to ensure robustness of our results. The first two tests include rerunning the DiD models with artificial treatment timing, and using an alternative treatment group, to falsify the treatment timing and treatment status, respectively. In the third test, we rerun our DiD models after dropping the COVID-19 period. The fourth experiment reruns estimations using a shorter event window, whereas the fifth uses a collapsed pre-post event window. We drop bank level controls and use entropy balancing matching method in the in the sixth and seventh tests. The eighth and ninth experiments drop high disequilibrium between returns on risky and safe assets, and use event studies with staggered treatment techniques, respectively. In the last test, we run our DiD model using equity returns as an alternative measure of aggregate level of risk.

7.1 | Timing effects

We do two separate experiments on the timing of 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 2 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 to 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)).

To further investigate the timing effects, we estimate the marginal treatment effects for each year in our sample. These effects are presented in Figure 2. Panel (a) shows that the average risk weights of LR banks show non-statistically significant increases relative to those of non-LR banks. Meanwhile the leverage ratios of LR banks (Panel (b)) started to increase relative to non-LR banks in 2015, and continued this trend in the following years, except for 2017. However, the differences between the treatment and control groups were not statistically significant, except in 2016. This suggests that most of the treatment effect of the level of leverage crystallised within 1 year of the introduction of the leverage ratio. This largely explains the patterns we observe in Panel (c), where CDS spreads of LR banks demonstrate the largest drop relative to those of non-LR banks in 2016. Smaller dropped appear in the following years, except in 2019. The results shown in the three panels are in line with our baseline results on asset risk, insolvency risk and the aggregate level of risk.

7.2 | Using an alternative treatment group

In this experiment, we drop 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

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	−0.0229	−0.363*	−0.318	0.817***	0.892	0.643	0.533	0.214
	(0.00495)	(0.0202)	(0.173)	(0.877)	(0.169)	(0.803)	(0.485)	(0.314)	(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	−21.04	0.540*	−1.716**	−0.302	0.0114	0.119	−0.00628	−0.279
	(2.181)	(14.25)	(0.317)	(0.712)	(0.323)	(0.247)	(0.387)	(0.203)	(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	0.0530*	−0.724	2.852	0.430	−0.873	0.581	−0.649*	5.593**
	(0.00593)	(0.0391)	(0.777)	(2.510)	(0.847)	(0.852)	(2.064)	(0.462)	(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

(Continues)

TABLE 5 (Continued)

Panel (b) CDS spreads on 5-year subordinated debt			
CDS spreads on 5Y subordinated debt	**Timing effects (EXP1)**	**Timing effects (EXP2)**	**Treatment status**
	(1)	**(2)**	**(3)**
Treated * *LR*	609.1***	37.62***	50.91***
	(65.67)	(10.35)	(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

Note: Panel (a): 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): 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, $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.
Abbreviation: LR, leverage ratio.

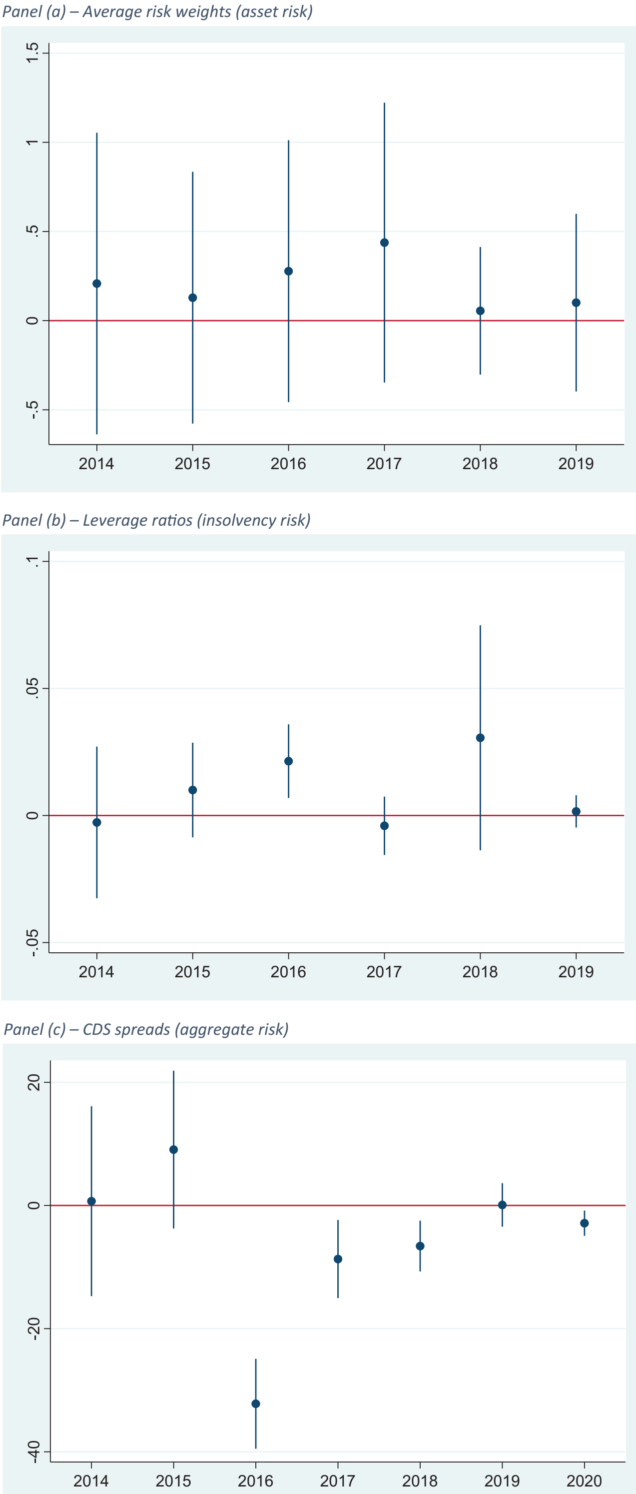

FIGURE 2 Timing effects (marginal treamnet effects) [Color figure can be viewed at wileyonlinelibrary.com]

in the baseline analysis. We then compare the behaviour of this alternative treatment group to the rest of the control group. The rational 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 for the decomposition of exposures by risk weight buckets, and CDS spreads of the (alternative) treatment group increase rather than decrease relative to control group (Table 5, 6).

7.3 | Results excluding the COVID period

As documented in recent literature (see Berger & Demirguc-Kunt, 2021, for a well-structured literature review on banking research during COVID-19), the COVID period represented a very different scenario from other crises. This is mainly due to its origin, outside the financial system as compared to the 2007–2008 crisis, its direction of causation, which was also not from banking issues, and the speed and cost of government interventions (Berger & Roman, 2020; Fatouh et al., 2021). 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 | 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 4-year event window around the introduction of leverage ratio (2 years before and after). Results of this test are presented in Table 6 , and are in line with the baseline results.

7.5 | Using a collapsed event window

Bertrand et al. (2004) point out that serial correlation in a DiD estimation can result in a downward bias in estimated standard errors. To address this issue, we rerun our baseline models using collapsed per-treatment and post-treatment periods. We create the collapsed periods by averaging our data before and after the introduction of leverage ratio in 2016. The DiD results for this experiment are reported in Table 7 and are consistent with the baseline results.

7.6 | Dropping controls

The existence of time-varying control variables may contaminate DiD estimations (Atanasov & 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.

7.7 | Using an alternative matching technique (entropy balancing)

Rather than using propensity score matching, in this experiment we employ the entropy balancing method suggested by Hainmueller and Xu (2013). This method assigns weights to banks in the control group to establish perfect overlapping of bank-level controls between the treatment and control groups. The advantage of entropy balancing is in its

TABLE 6 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**	**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*	0.0645***	−0.0688	2.083	4.571	1.266	−1.300	2.953	0.347	−2.692
	(0.0157)	(0.0514)	(1.930)	(3.870)	(0.923)	(1.087)	(2.427)	(0.245)	(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

(Continues)

TABLE 6 (Continued)

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

Note: Panel (a): 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): 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, * $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$.
Abbreviation: LR, leverage ratio.

TABLE 7 Robustness tests—Collapsed per-treatment and post-treatment periods

Panel (a) lending leverage ratio, average risk weights and decomposition of exposures by risk weight buckets									
	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
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Treated * *LR*	0.0134**	−0.189	−3.364	3.152	−0.378	−2.406	5.654	1.452	−5.354
	(0.00882)	(0.131)	(5.88)	(4.87)	(2.64)	(3.30)	(1.46)	(7.64)	(8.698)
Observations	84	84	70	56	84	84	77	84	63
R-squared	0.999	0.990	1.000	1.000	1.000	1.000	1.000	1.000	1.000
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) CDS spreads on 5-year subordinated debt									
CDS spreads on 5Y subordinated debt									
Treated * *LR*									−76.44***
									(4.242)
Observations									53
R-squared									0.963

(Continues)

TABLE 7 (Continued)

Panel (b) CDS spreads on 5-year subordinated debt	
CDS spreads on 5Y subordinated debt	
Controls	YES
Controls * **LR**	YES
LR	YES
Bank FEs	YES

Note: Panel (a): 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. Controls are averaged pre and post treatment, and include 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): 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. Controls are averaged pre and post treatment, and include 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.
Abbreviation: LR, leverage ratio.
$^{*}p < 0.10$.
$^{**}p < 0.05$.
$^{***}p < 0.01$.

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									
	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**
Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**
Treated * *LR*	0.0246***	−0.0961	0.188	−2.870	−0.920	1.156	−0.0692	0.701	−2.255
	(0.00232)	(0.0424)	(0.885)	(3.433)	(0.668)	(1.700)	(0.986)	(1.180)	(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
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

Note: Panel (a): 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): 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, $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.
Abbreviation: LR, leverage ratio.

independence of limitations arising from researcher's discretion on the specifications of the matching model or the number of matches. It also eliminates the need to drop certain controls to accommodate matching. Nevertheless, we argue that propensity score matching is better as a baseline approach in the current experiment. Due to the nature of banks the treatment group, we think comparing them to the entire control group, even with weighing, could lead to misleading results, given the significant business model differences. The outcome of DiD regressions based on entropy balancing are presented in Table 9 and show similar patterns to those in our baseline regressions.

7.8 | 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 lending to small and medium enterprises (SMEs) and gilts yields to calculate representative risk-adjusted capital-adjusted returns for risky and safe assets. 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 10 , and are consistent with the baseline results.

7.9 | Event study with staggered treatment

Following Sun and Abraham (2021), we run our models using a staggered treatment setup. While we do not have staggered rollout (there is one treatment period only), we use approach as a further test for our baseline assessment. Results for asset risk, the level of leverage and aggregate level of risk (Figure 3) are consistent with our baseline assessment.

7.10 | Using an alternative measure of aggregate risk

Instead of using CDS spreads, in this experiment we run our baseline DiD regression for the aggregate level of risk using equity returns. These returns allow us to measure risk based on the market perception of aggregate risk. We collect weekly share returns for banks listed in London Stock Exchange between 2014 and 2022. Results of DiD regressions of weekly share returns are presented in Table 11 . As the results suggest, the weekly returns on LR banks' shares fell by around 20 bps compared to non-LR banks, implying that investors perceived LR banks as less risky post the introduction of leverage ratio. The treatment effect falls to 12.5 bps if the COVID period was excluded, supporting our argument that investors viewed LR banks more resilient, especially in stress.

8 | CONCLUSION

The leverage ratio was introduced as part of the post 2007–2008 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

TABLE 9 Robustness tests—DiD results based on entropy balancing method.

Panel (a) lending leverage ratio, average risk weights and decomposition of exposures by risk weight buckets									
	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
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Treated * *LR*	0.0526***	−0.0129	0.433	−0.856	0.255	−0.185	−0.310	−0.0631	0.0425
	(0.0127)	(0.0294)	(1.102)	(1.425)	(0.290)	(0.187)	(0.239)	(0.150)	(0.290)
Observations	3,915	3,915	3,799	1,468	3,844	3,684	2,659	3,832	2,689
R-squared	0.182	0.078	0.368	0.334	0.205	0.401	0.206	0.383	0.179
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) CDS spreads on 5-year subordinated debt									
CDS spreads on 5Y subordinated debt									
Treated * *LR*									−238.8***
									(30.64)
Observations									23,984
R-squared									0.225
LR									YES
Controls									YES
Controls * **LR**									YES
Bank FEs									YES

Note: Panel (a): Coefficient estimates of quarterly regulatory exposures of banks from 2014 Q1 to 2020 Q4 using entropy balancing. 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: Coefficient estimates of daily CDS spreads on 5-year subordinated debt from 1 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, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Abbreviation: LR, leverage ratio.

TABLE 10 Robustness tests—DiD results based on periods with low disequilibrium between returns on SME lending and gilts

Panel (a) lending leverage ratio, average risk weights and decomposition of exposures by risk weight buckets									
	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
Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**
Treated * *LR*	0.0591**	0.203	6.948	3.236	1.948	−1.789	−0.388	0.916	−4.662
	(0.0231)	(0.9918)	(5.046)	(3.783)	(1.795)	(1.809)	(3.480)	(1.374)	(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
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

Note: Panel (a): 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): Coefficient estimates of daily CDS spreads on 5-year subordinated debt from 1 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, $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Abbreviation: LR, leverage ratio.

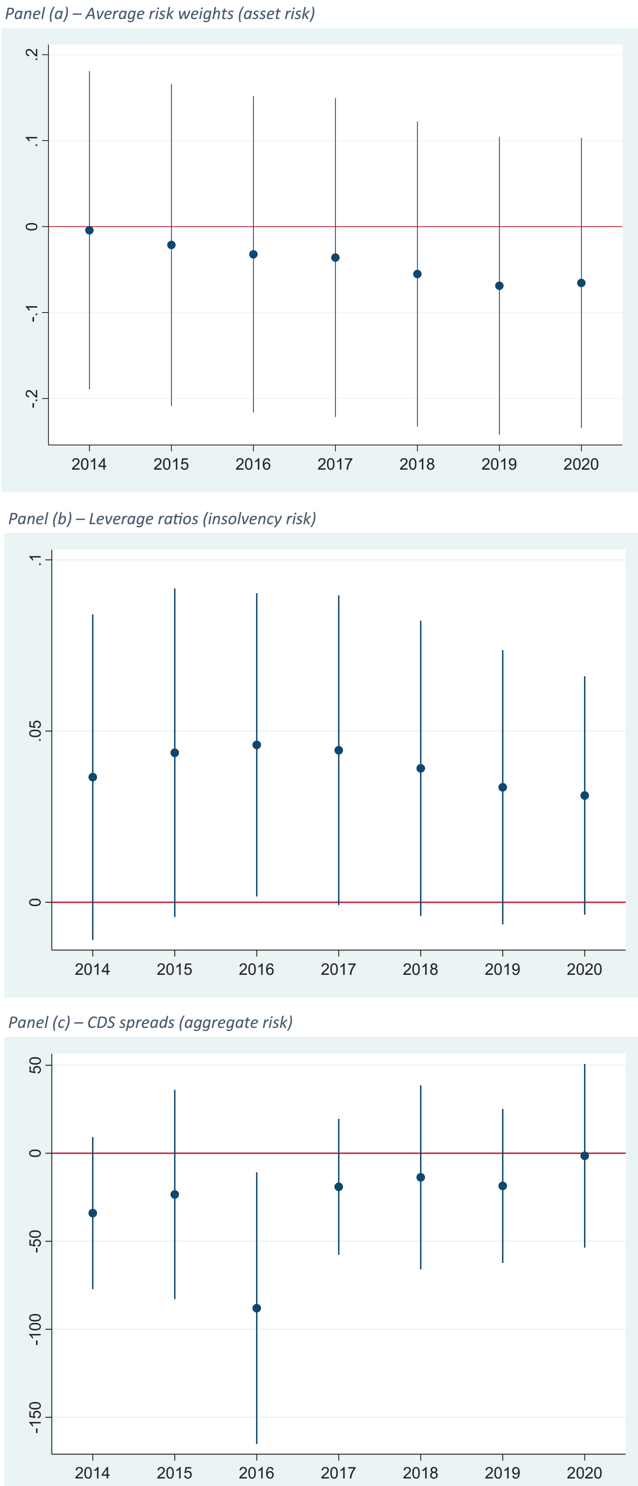

FIGURE 3 Event study with staggered treatment [Color figure can be viewed at wileyonlinelibrary.com]

TABLE 11 DiD results for weekly equity returns

Weekly equity returns	Including COVID period (1)	Excluding COVID period (2)
Treated * *LR*	−0.198***	−0.125**
	(0.0712)	(0.0642)
Observations	6,500	5,492
R-squared	0.012	0.017
LR	YES	YES
Controls	YES	YES
Controls * **LR**	YES	YES
Bank FEs	YES	YES

Note: Coefficient estimates of weekly equity returns from 1 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.
Abbreviation: LR, leverage ratio.
$^{*}p < 0.10$.
$^{**}p < 0.05$.
$^{***}p < 0.01$.

with risk-based requirements sets a de facto 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 between 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-differences (DiD) setup, 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 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 more resilient, especially during COVID stress.

Our results are highly relevant to policymakers. They indicate that the leverage ratio has so far attained its objective of preventing the build-up of leverage in the banking system, while not causing unintended consequences in terms of inducing banks to take more risk. As such, our paper represents a strong addition to the evidence regulators and the Basel Committee on Banking Supervision can rely on to evaluate the post-crisis regulatory reforms.

Lastly, we note that our exercise does not directly consider the potential fundamental differences in loan demand for banks. A further extension of our exercise can employ loan level data linked to proxies for regional economic activity together with banks' presence at region level to control for loan demand side.

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ENDNOTES

[1] 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

[2] 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).

[3] 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.

[4] 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 became applicable to all banks with foreign exposures of £10 billion or more.

[5] 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.

[6] When it was introduced in the UK in 2016, 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. A 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 business 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 requirements of each unit (e.g., Bank of England, 2018). In this case, the leverage ratio would be effectively applied at the business unit-level. 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).

[7] 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.

[8] See Appendix A3 for an illustration.

[9] 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). There are no marginal cases (i.e., banks with retail deposits approaching the £50 bn threshold), as the control bank with largest retail deposits, had less than £25 bn in such deposits.

[10] This changed in 2023, when the leverage ratio became applicable at all levels of consolidation. However, this is outside the scope of our sample.

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

[12] Since our database includes few treated banks, we try several matching ratios (from 1:4 to 1:10) using the covariates from a probit model that regresses the treatment dummy on bank size (log of total leverage ratio exposures), risk density (risk weighted assets over total leverage exposures), business model (proxied by total securities over total leverage exposures and off-balance sheet exposure over total leverage exposures), and capitalisation (Tier 1 capital over risk weighted assets). Matching results are generally consistent and confirm that we cannot reject the hypothesis that all coefficients are zero in the post-matching models. We opt for 1:5 matching ratio since it minimises post-matching differences between the treatment and control groups, showing also the best compromise in terms of *p*-values and groups size. The results of matching using other matching ratios are non-tabulated and available from the authors upon request.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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