BANK OF ENGLAND

# Staff Working Paper No. 956

# Not bound, but still relevant: How does the leverage ratio affect banks' intermediation?

Ioana Neamtu and Quynh-Anh Vo

December 2025

This is an updated version of the Staff Working Paper originally published on 17 December 2021

BANK OF ENGLAND

# Staff Working Paper No. 956

# Not bound, but still relevant: How does the leverage ratio affect banks' intermediation?

Ioana Neamtu[(1)] and Quynh-Anh Vo[(2)]


## Abstract

This paper explores the mechanism that makes banks that are not bound by the leverage ratio reduce their repurchase agreement (repo) intermediation. Despite the leverage-intensive nature of repo activities, it remains unclear why such banks would decrease their repo business. We argue that this behaviour stems from banks' internal capital allocation practices of applying regulatory requirements at the business-unit level instead of the consolidated level. To this end, we develop a theoretical model of banks with multiple business units and calibrate it to the UK banking sector. We show that applying regulatory requirements at the business-unit level leads to a disproportionate reduction in the repo operations among banks that are unconstrained by the leverage ratio. We also find that this impact varies across different bank business models.



**Key words:** Leverage ratio requirement, risk-weighted capital requirement, banks' internal capital allocation, repurchase agreements.

**JEL classification:** G21, G28.



(1) Federal Reserve Board. Email: ioana.neamtu@frb.gov

(2) Corresponding author. Bank of England. Email: quynh-anh.vo@bankofengland.co.uk



We are grateful for helpful comments from Tirupam Goel and Bill Francis; from discussants Sebastian Doerr, Lenka Fiala, George Pennacchi, Adrian Pop and from Arnoud Boot, Tom Crossland, Sebastian Gryglewicz, Aakriti Mathur, Ieva Sakalauskaite, Arzu Uluc, Razvan Vlahu, Matthew Willison as well as participants at 2024 EEA, 2023 IBEFA Summer meeting, 2022 AEA, 2021 FDIC/JFSR Bank Research Conference, WinE EEA 2021, EFMA 2021, GdRE Symposium on Money, Banking and Finance 2021, and Bank of England seminars. All remaining errors are our own. A previous version was circulated under the title: 'Banks' internal capital allocation, the leverage ratio requirement and risk-taking'. The views expressed in this paper are those of the authors and not necessarily those of the Bank of England or its Committees, nor should they be interpreted as reflecting the views of the Board of Governors of the Federal Reserve System or of anyone else associated with the Federal Reserve System.

The Bank's working paper series can be found at www.bankofengland.co.uk/working-paper/staff-working-papers

Bank of England, Threadneedle Street, London, EC2R 8AH
Email enquiries@bankofengland.co.uk




ISSN 1749-9135 (on-line)

# 1 Introduction

The introduction of the leverage ratio (LR) requirement for banks in the aftermath of the Great Financial Crisis (GFC) of 2007-2009 was meant to restrict the leverage build-up in the banking system and act as a backstop for the risk-weighted (RW) requirement. However, its risk-insensitive nature raised concerns about adverse consequences on low risk and low return activities of banks. Among such activities, banks' incentives to intermediate in the government-securities repurchase agreement (repo) market attracted significant attention (e.g., Duffie (2017)) due to its crucial role in facilitating the flow of cash and securities in the financial system. More recently, the effects of the LR requirement have regained a central stage in policy making amid growing concerns about its impact on the functioning of Treasury markets.[1]

Several analyses find both theoretically and empirically that banks bound by the LR requirement will shift away from low-risk, low-profit businesses such as repos (e.g., Kiema and Jokivuolle (2014), Kotidis and Van Horen (2019), Acosta-Smith, Grill and Lang (2020)).[2] However, for banks where the LR does not appear to be binding, while extant theoretical analyses do not suggest any impact of the LR on their investments, there exists evidence that those banks also reduce their repo activities (e.g., Committee on the Global Financial System (2017), Allahrakha, Cetina and Munyan (2018) and Bassi, Behn, Grill and Waibel (2024)). What contributed to non-LR bound banks to also limit their repo intermediation business? In this paper we explore a mechanism that rationalises this empirical fact, and our results can help contribute to the policy debate on the LR evaluation.

Our core explanation is rooted in the so-called internal capital allocation process that banks undertake. This is the method that banks use to determine the notional amount of

[1] See, for instance, the Speech by Governor Bowman, Vice Chair for Supervision of the Board of Governors of the Federal Reserve System, in June 2025 (Bowman, 2025).

[2] Other papers examine the impact of the LR requirement on banks' participation in the government bond market and find similar effects (e.g., Favara, Infante and Rezende (2024)).

equity needed to support each business unit. An important finding from supervisory reviews on banks' capital allocation approaches is that, even though the LR is legally imposed at the consolidated level only, some banks *actually* choose to apply the LR requirement at the business-unit level.[3] We argue that such practices can be the origin for the reduction in repo intermediation observed in banks unconstrained by the LR.[4]

We develop this argument in a model in which a banking group with multiple business units selects optimal investments in the presence of multiple regulatory capital requirements. We characterise analytically how applying regulatory constraints at the business unit level impacts the bank's asset composition. We then take the model to the data and run numerical simulations using proprietary and confidential regulatory data on retail lending and repo activities of UK banks. The simulation of the calibrated model verifies the empirical relevance of our analytical findings and complements them with insights into differing investment adjustments across banks' business models.

Our main contribution is to provide a novel explanation for why the LR affects the repo activities of banks that are seemingly not affected by this regulation. This insight helps clarify why the LR may have *a larger and more disproportionate impact* on banks' liquidity provision than previously anticipated. Our analysis also carries important policy implications, as the level at which the LR is applied remains a key consideration for regulators. In particular, it highlights a potential cost that policymakers should account for if they choose to impose the LR at levels below the consolidated group.

[3] The UK Prudential Regulation Authority (PRA) conducted several supervisory reviews on banks' capital allocation approaches. The key findings of these reviews are documented in Bajaj, Binmore, Dasgupta and Vo (2018) and further supported in the Basel Committee on Banking Supervision (BCBS) working paper by Da Rocha Lopes, Foos, Janowski, Schmitz, Tomova and Yung (2025). The observations from these reviews align with broader patterns in other banks' practices such as the imposition of risk limits on trading desks or banks' limited ability to reallocate High Quality Liquid Assets (HQLA) across businesses, which are documented in several papers (e.g., Lu, Macchiavelli and Wallen (2023); Barbiero, Bräuning, Joaquim and Stein (2024); Li, Petrasek and Tian (2024); Bräuning and Stein (2025)).

[4] In this paper, we do not seek to examine the optimality of banks' internal capital allocation approaches but take them as given. We therefore focus on the positive implications of banks' operational practices linked to prudential regulation on banks' investments.

Our stylised baseline model features a risk-neutral banking group that runs two business units. One unit has higher non-risk adjusted returns but is risky, while the other has lower returns and is risk-free. To focus on the impact of the LR requirement on banks' repo activities, we model the risk-free business as repo intermediation while the risky business resembles a lending business. The bank finances its activities with debt and a fixed amount of equity capital that it will allocate to its two business units. The bank is subject to two requirements, namely the RW capital requirement and the LR requirement, which are legally imposed at the group level.

To capture banks' internal capital allocation practices, we consider the case where the banking group allocates equity capital such that each business unit must be assigned enough equity capital to make them comply with both regulatory constraints. We hereafter refer to it as the allocation of regulatory constraints to business units or interchangeably as the application of regulatory constraints at the business-unit level. We compare the resulting bank's optimal investments in this case to the case where the bank applies the two regulatory requirements only at the group level as legally required. We assess how the composition of the bank's asset portfolio differs between the two cases.

One of the main analytical findings in our baseline model is related to the asset composition of the banking group when it is only bound by the RW requirement, and not by the LR. In this case, we find that allocating requirements to business units can induce the bank to invest less in repo and more in lending. Investment decisions are based on comparing the returns on investment with the cost of capital needed for that business. This in turn is determined by the binding regulatory constraint.

Therefore, when requirements are applied at the group level and the group is bound by the RW requirement, the bank's incentives to invest in the two business units are determined by *the marginal RW capital cost* - the additional equity capital required by the RW requirement for each additional unit of investment. However, when the bank applies requirements at the business-unit level, there are situations where the binding constraint for the repo business unit is the LR requirement. As such, the cost of investing in repos is now determined by *the marginal leverage cost* - the additional equity capital required by the LR requirement for each additional unit of investment. As repo activities generally incur higher leverage costs than RW capital costs, the banking group will invest less in repo when it applies requirements at the business-unit level instead of the group level.

To complement our theoretical analysis, we generalise the baseline model and calibrate it using data on a sample of UK banks. When simulating the calibrated model, we find that the allocation of constraints to business units leads to a disproportionate reduction of repo activities for the average bank in our sample when only the RW requirement binds at the group level. This result confirms the empirical relevance of our analytical finding described above.

We then examine whether banks with different business models adjust their investments similarly by recalibrating the model separately for wholesale and retail banks. We find that allocating constraints down to business units is especially detrimental for repo intermediation of retail banks when the RW constraint is binding, with little effect on the wholesale banking intermediation.

**Related literature** Our paper is related to several strands of literature.

The first strand assesses the impact of the LR requirement on banks' asset composition.[5] Kiema and Jokivuolle (2014) and Acosta-Smith, Grill and Lang (2020) study the effects of introducing a LR requirement in addition to the RW requirement on banks' credit allocation and stability. They suggest that the LR requirement, *when it is binding*, will induce banks to increase risk-taking by reducing investments in safer assets. However, this risk-taking effect is counterbalanced by the benefits of increased capital, thereby leading to increased stability.

[5] Other work analyses how the LR affects banks' incentives to truthfully report their riskiness (Blum, 2008) and how it interacts with the RW requirement to affect the business cycle (Gambacorta and Karmakar, 2018).

Consistent with a shift to riskier assets, Choi, Holcomb and Morgan (2020) found that US banks subject to the LR requirement shifted investment to higher yield securities, regardless of how binding the LR requirement was. Our paper adds to this literature by highlighting that the LR impact on banks' asset composition depends on the business level at which banks apply this regulation. If banks choose to allocate this regulatory constraint to their business units, then even a *non-binding* LR requirement can also induce them to reduce investments in low-risk activities. Moreover, instead of focusing on the implications of changes in banks' asset composition on banks' stability, our paper emphasises the implications of such changes for banks' ability to provide liquidity to key markets via their repo activities.

Second, our analysis relates to the growing literature on how frictions arising from banks' (self-imposed) risk-bearing constraints affect market liquidity and asset prices. Using US data on internal risk limits at the trading desk level collected under the Volcker Rule, Barbiero, Bräuning, Joaquim and Stein (2024) examine FX trades and show that these constraints affect currency returns and deviations from the covered interest parity. Bräuning and Stein (2025) and Li, Petrasek and Tian (2024) focus on the effects of these risk limits on the liquidity of the Treasury markets.[6] These studies reveal that banks impose stand-alone risk constraints at a very granular level and do not allow for cross-subsidisation of capital, thus introducing frictions into their financial intermediation capacity. Moreover, such frictions are not limited to capital requirements. Lu, Macchiavelli and Wallen (2023) find that secured lending spreads are adversely affected, likely due to the banks' limited ability to reallocate their High Quality Liquid Assets (HQLA) between different businesses. Our paper focuses on frictions that stem from imposing regulatory constraints on business units, and our theoretical framework and assumptions support the above empirical findings.

Our paper is also related to studies on the banks' internal capital market. The most

[6] Also, Lu and Wallen (2024) exploit similar data to analyse financial intermediation behaviour across numerous trading assets.

related to our paper is Goel, Lewrick and Tarashev (2020), which examines how banks allocate capital when facing multiple constraints.[7] The authors show that when a constraint tightens for one business unit, it will lead to spillover effects for other unaffected units, as capital will be relocated to the most profitable unit per marginal cost of capital. The main difference is that Goel, Lewrick and Tarashev (2020) assume directly that regulatory constraints are applied at the business-unit level. Therefore, their paper cannot explain how banks' investment decisions differ between the business-unit level application and the group-level application of regulations, which is the main focus of our paper.

Finally, we also contribute to the literature measuring the impact of the LR requirement on banks' incentives to undertake market-making, especially repo activities. Several studies documented how banks not bound by the LR reduced their repo business in the US (Allahrakha, Cetina and Munyan (2018)), the UK (Bicu-Lieb, Chen and Elliott (2020)) and across European repo markets (Bassi, Behn, Grill and Waibel (2024)). Anbil and Senyuz (2022) also show that dealers subject to end-of-quarter LR reporting reduced their intermediation around that time. Our paper offers an explanation of the mechanism underlying the impact of the LR on repo business found in these empirical analyses. Other works show how dealers price-in the LR in their repo (Gerba and Katsoulis (2025)) and Treasury market operations (He, Nagel and Song (2022)), and how they shift repo intermediation to market segments with less impact on the LR calculation during times of stress (Hüser, Lepore and Veraart (2024)). Negative effects on market-making when faced with a LR constraint were also documented for FX derivatives (Cenedese, Della Corte and Wang (2021)), options (Haynes and McPhail (2021)), Treasuries (Li, Petrasek and Tian (2024), Favara, Infante and Rezende (2024)), and corporate bonds (Breckenfelder and Ivashina (2021), Giannetti,

[7]Other contributions include Krüger, Landier and Thesmar (2015), who empirically show that the allocation based on the firm-wide cost of capital leads to under-investment in safer businesses and over-investment in relatively riskier ones. Perold (2005) instead discusses how accounting for diversification benefits between different businesses can reduce banks' economic capital needs.

Jotikasthira, Rapp and Waibel (2024)).

The paper proceeds as follows. Section 2 briefly outlines the institutional background. Section 3 sets out a stylised model and presents the main analytical insights. In Section 4, we introduce a generalised model, which serves as the basis for subsequent calibration. Section 5 details the calibration procedure and discusses the results of the numerical simulations. Finally, Section 6 concludes.

## 2 Institutional Background

In this section, we detail the regulatory environment and institutional characteristics that are central to our analysis. We first explain the role of the LR requirement and its link to repo intermediation, and then we provide background on banks' internal capital allocation process.

**LR requirement and repo intermediation** The build-up of leverage in the banking system was an underlying cause of the GFC. In the run-up to the crisis, many banks built up excessive leverage while maintaining seemingly strong risk-based capital ratios. To address this issue, the Basel Committee introduced a minimum LR in the Basel III framework as a non-risk-based "backstop" to the risk-based capital requirements. The leverage ratio captures off-balance sheet positions, and it is also meant to be counter-cyclical, addressing past issues of large and unaccounted off-balance sheet positions of banks and excessive leverage taken in times of economic boom.[8]

The LR is defined as the Tier 1 capital divided by the leverage exposure measure, the latter being the sum of the dollar amount of on-balance sheet and off-balance sheet exposures. The minimum LR requirement, therefore, is a risk-insensitive constraint. It requires banks

[8] Our paper does not assess the overall costs and benefits of the leverage ratio. However, Gambacorta and Karmakar (2018) provides a useful general equilibrium framework to evaluate the impact of introducing a leverage ratio. The paper finds that it indeed acts as a backstop and its benefits outweigh the costs.

to have the same amount of equity capital for each unit of assets, regardless of their riskiness. Consequently, it was expected to penalise disproportionally banks' low-risk activities since intermediation of low-risk assets is typically less profitable than intermediation of high-risk assets.

Policy makers and academics have warned against the adverse impact of the LR requirement on banks' ability to intermediate markets for safe assets such as the market for repurchase agreements backed by government securities (see, for example, the Speech by the Vice Chair for Supervision of the Board of Governors of the Federal Reserve System (Bowman, 2025)). The Committee on the Global Financial System cited the leverage ratio as one of the drivers of the limited availability and higher cost of repo financing in their 2017 report on repo market functioning. Duffie (2017), among others, claimed that the US Supplementary Leverage Ratio (SLR) has especially impaired the liquidity of the Treasury repo market.

**Banks' internal capital allocation** Banks always seek to optimize business decisions in order to maximize returns for a given set of financial constraints. Capital allocation is an important process that banks use in practice to drive those business optimization decisions. Through this process, banks will determine the notional amount of equity capital needed to support each of their businesses. Capital allocation facilitates the banks' assessment of relative performance across their business units because it enables banks to evaluate the profitability of each individual business against its use of equity capital - a scarce financial resource.

When setting up a capital allocation framework, banks must determine how to incorporate the regulatory constraints they face. In the aftermath of the GFC, both the number and complexity of these constraints increased significantly, with banks now required to comply with multiple capital and liquidity standards. This has posed operational challenges for banks in adapting their internal capital allocation practice to the new regulatory landscape (see e.g., Khaykin, Koyluoglu, Elliott and Spicer (2017)). Supervisory reviews (e.g., Bajaj, Binmore, Dasgupta and Vo (2018) and Da Rocha Lopes, Foos, Janowski, Schmitz, Tomova and Yung (2025)) find that, facing such challenges, some banks determine the amount of equity capital allocated to each business unit by the maximum amount of capital required by all regulatory constraints they are subject to. This is equivalent to requiring each business to have sufficient equity capital to comply with all regulatory constraints.

The banks' practice of imposing regulatory constraints at levels below the group consolidation is conceptually analogous to their practice of imposing internal risk limits at granular levels such as individual trading desks. Drawing on data collected under the Volcker Rule, several papers (see, for examples, Li, Petrasek and Tian (2024), Bräuning and Stein (2025) and Anderson, McArthur and Wang (2023)) document that banks' self-imposed quantitative limits encompass both risk-sensitive and risk-insensitive constraints. The most common risk-sensitive limits are based on value-at-risk (VaR) while risk-insensitive limits include limits on the size of a desk's portfolio measured either by market value or gross-notional value. Those limits are set to manage risk-taking behaviour and the allocation of capital resource across trading desks, even though they may come at the expense of forgoing profitable trading opportunities.

# 3 A simple model

In this section, we present a stylised model of a banking group with multiple business units, designed to illustrate the core intuition. We begin by outlining the economic environment, followed by an analysis of banks' optimal investment decisions.

### 3.1 Environment

We consider a banking group that is funded by a fixed amount of equity capital $K$ and debt with a gross interest rate $R$. It runs two business units, namely a lending business and a repo business. For simplicity, we assume that the lending business is risky while the repo business is risk-free.

**Two business units:** The lending unit grants loans to customers. We denote the bank's ex-ante gross interest income from loans by $G(L)$ where $L$ is the total value of granted loans. We capture the fact that granting loans is a risky business by assuming that ex-post only a fraction $p$ of total loans will pay off. Therefore, the bank's ex-post lending revenue is equal to $pG(L)$.

The repo unit owns a stock of government bonds of value $X$ with coupon normalised to zero. It uses this inventory to raise collateralised funding to finance bond trading activities or to act as an intermediary entering into repo transactions with some counterparties and offsetting reverse repos with others. Those activities generate a deterministic income denoted by $F(X)$.

We make the following assumption on the profitability of the two business units:

**Assumption 1.** *Functions $G(.)$ and $F(.)$ satisfy the following conditions:*

$$G(0) = 0; \quad G'(.) > 0 \quad \textit{and} \quad G''(.) < 0$$

$$F(0) = 0; \quad F'(.) > 0 \quad \textit{and} \quad F''(.) < 0$$

Assumption 1 implies that both lending and repo businesses have diminishing marginal returns. For the lending business, this property can be explained by, for example, the downward sloping loan demand that banks face. For the repo business, this can be because the interest rate of reverse repos is less sensitive to the transactional amount than the repo rate, which in turn can come from the market power of banks in both activities.

**Assumption 2.** *The rank of profitability between the two business units is as follows:*

$$pG'(y) > F'(y) \quad \textit{for all} \quad y$$

Assumption 2 indicates that the lending business is more profitable than the repo business on a non-risk-adjusted basis.

**Regulatory constraints and internal capital allocation** The bank is subject to two regulatory constraints, namely the LR requirement and the RW capital requirement. Among the total equity capital $K$ that the bank has, $K_L$ will be allocated to support the lending business while $K_X$ is allocated to the repo business.

**Assumption 3.** *The lending business has risk weight equal to 100% while the repo business has zero risk-weight.*

In this stylised setting, as stated in Assumption 3, we assume that the lending business carries an exogenous risk weight of 100% while the repo business has zero risk-weight as it is assumed to be risk-free. The risk-weighted assets (RWAs) of the bank at the group level, which we denote by $RWA^G(L, X)$, is therefore equal to:

$$RWA^G(L, X) = L$$

Let $\gamma$ be the required RW capital requirement. The group-level RW requirement can be written as follows:

$$K \geq \gamma L \tag{1}$$

The LR requirement is expressed in terms of the ratio of equity capital to leverage exposure. The leverage exposure of the lending unit is equal to its size L. For the repo unit, due to the different possible regulatory treatments of repo activities, its leverage exposure can be a multiple of its size $X$. For example, when the bank runs a matched repo book, if all reverse repo transactions are not eligible for netting, due to the requirement that securities sold as collateral cannot be removed from the banks balance sheet, the leverage exposure of the repo business will be equal to $2X$. To capture this characteristic of repo activities, we assume that the leverage exposure of the repo unit equals $\alpha X$ where $\alpha \in [1, 2]$.[9] Therefore, the LR requirement at the group level is as follows:

$$K \geq \chi(L + \alpha X) \tag{2}$$

where $\chi$ is the required LR. In line with the Basel III framework, we assume that $\chi < \gamma$.

When the bank chooses to allocate regulatory constraints down to its business units, the allocated capital $K_L$ and $K_X$ are determined so that both business units have enough equity capital to comply with both regulatory constraints individually. Given Assumption 3, the RWAs of the lending business on a stand-alone basis - denoted by $RWA^L(L)$ - equal $L$ while the repo business carries zero RWAs, i.e., $RWA^X(X) = 0$. Therefore, $K_L$ is such that the lending business has to satisfy:

$$K_L \geq \gamma RWA^L(L) = \gamma L \quad \text{and} \quad K_L \geq \chi L \tag{3}$$

while $K_X$ is determined so that the repo business satisfies:

$$K_X \geq 0 \quad \text{and} \quad K_X \geq \chi \alpha X \tag{4}$$

**Bank's expected profit**: We denote by $\tilde{\Pi}_L$ and $\Pi_X$ the profit of, respectively, the lending

[9]Note that the results stated in the following analysis will apply to other types of low risk and low return businesses when $\alpha$ is set to 1.

and repo units.[10] We have:

$$\mathbb{E}\left(\tilde{\Pi}_L\right) = pG(L) - R(L - K_L) \quad \text{and} \quad \Pi_X = F(X) - R(X - K_X)$$

The overall expected profit of the whole banking group is thus equal to $\mathbb{E}\left(\tilde{\Pi}_L + \Pi_X\right)$.

## 3.2 Analysis

We now examine the bank's optimal investments. Our primary objective is to understand how the bank's incentives to invest in each business are affected by the level at which the two regulatory constraints are applied. For that purpose, we define $w$ as the fraction of the bank's total balance sheet allocated to the lending business, i.e.,

$$w = \frac{L}{L + X}$$

Our goal is to compare the bank's optimal choice of $w$ between two cases: one in which both constraints are applied at the group level and another in which each business unit must individually comply with both regulatory constraints. If $w$ is lower in the former case, this indicates that the allocation of regulatory constraints to business units *disproportionately* discourages investments in the repo business.

To get started, we first formulate the bank's profit-maximisation problem for each of these two scenarios. Then, we examine how the bank's investment decisions differ.

### 3.2.1 Bank's optimisation problems

**Optimisation problem with constraints applied at the group level** When all constraints are applied at the group level, the bank's optimisation problem, denoted as $\wp^G$,

[10] We include a tilde in the notation for the lending business's profit to indicate that it is a random variable.

can be written as follows:

$$Problem \quad \wp^G : \qquad \underset{L,X}{\text{Max}} \quad \mathbb{E}\left(\tilde{\Pi}_L + \Pi_X\right)$$

subject to Constraints (1) and (2)

To facilitate the examination of how the bank's asset composition $w$ would change depending on the application level of the two regulatory constraints, we reformulate Problem $\wp^G$ by changing the bank's decision variables from $(L, X)$ to $w$ and the size of the bank's total balance $S = L + X$. After expressing $L$ and $X$ in terms of $S$ and $w$, Problem $\wp^G$ could be rewritten as:

$$\underset{S,w}{\text{Max}} \quad \{pG(wS) + F((1-w)S) - RS + RK\}$$

subject to

$$K \geq \gamma RWA^G(w, S) = \gamma wS \tag{5}$$

$$K \geq \chi \left(wS + \alpha(1-w)S\right) \tag{6}$$

**Optimisation problem with constraints allocated down to business units** When the bank allocates two constraints to its business units, the bank's optimisation problem, denoted as $\wp^B$, is as follows:

$$Problem \quad \wp^B : \qquad \underset{L,X}{\text{Max}} \quad \mathbb{E}\left(\tilde{\Pi}_L + \Pi_X\right)$$

subject to the four constraints described in (3) and (4) as well as the internal capital allocation constraint:

$$K \geq K_L + K_X$$

We can reformulate Problem $\wp^B$ in terms of $w$ and $S$ as:

$$\underset{S,w}{\text{Max}} \quad \{pG(wS) + F((1-w)S) - RS + RK\}$$

subject to

$$K_L \geq \gamma RWA^L = \gamma wS \tag{7}$$

$$K_X \geq 0 \tag{8}$$

$$K_L \geq \chi wS \tag{9}$$

$$K_X \geq \chi\alpha(1-w)S \tag{10}$$

$$K \geq K_L + K_X \tag{11}$$

#### 3.2.2 Bank's optimal investments

We are now equipped to compare the bank's investments between the two scenarios defined above as Problems $\wp^G$ and $\wp^B$, with solutions $(w^G, S^G)$ and $(w^B, S^B)$.

To get a first intuition about how bank investment decisions differ, we compare the constraints of Problem $\wp^G$ with those of Problem $\wp^B$. We note that both the group-level RW and the group-level LR constraints are weakly looser than the respective business unit-level constraints. This observation implies that applying regulatory constraints at the business unit level will weakly reduce the set of investment opportunities available to the bank. The following proposition highlights the impact on the total size of the bank's balance sheet when both constraints are applied at the business unit level.

**Proposition 1.** *Bank's balance sheet size:*

$$S^B \leq S^G$$

*Proof.* It is a direct consequence of the fact that the constraints of Problem $\wp^B$ are weakly tighter than those of Problem $\wp^G$. □

We now turn to the impact on the bank's asset composition $w$. Using the Lagrangian associated with Problems $\wp^G$ and $\wp^B$, we can write the first order conditions (FOCs) that characterise $w^G$ as

$$\left[pG'(w^G S^G) - R\right] - \left[F'((1-w^G)S^G) - R\right] = \lambda_{VaR}\gamma + \lambda_{LR}\chi(1-\alpha) \tag{12}$$

and $w^B$ as:

$$\left[pG'(w^B S^B) - R\right] - \left[F'((1-w^B)S^B) - R\right] = \lambda^L_{VaR}\gamma + \lambda^L_{LR}\chi - \lambda^X_{LR}\alpha\chi \tag{13}$$

where $\lambda_{VaR}, \lambda_{LR}, \lambda^L_{VaR}, \lambda^L_{LR}$ and $\lambda^X_{LR}$ are the shadow price of, respectively, Constraints (5), (6), (7), (9) and (10).[11]

Comparing Constraint (5) and Constraint (6), we see that whether the bank is constrained by the LR or by the RW requirements at the group level depending on the comparison between the following two terms:

$$\frac{wS}{wS + \alpha(1-w)S} \quad \text{and} \quad \frac{\chi}{\gamma}.$$

The former term represents the average risk weight (ARW) - defined as the ratio of RWAs over leverage exposure - of the bank at the group level while the latter is the critical average risk weight (CRW) - the ratio of required LR over the required RW capital ratio. Our main interest lies in the case where the banking group is bound by the RW requirement. But to facilitate the comparison, we examine first the case where the bank is bound at the group

[11] See Appexdix A.1 for the detailed derivation.

level by the LR requirement.[12]

**LR-constrained bank** The bank is bound by the LR requirement at the group level when the following conditions holds:

$$ARW^G(w,S) = \frac{wS}{wS + \alpha(1-w)S} < \frac{\chi}{\gamma}$$

We state in the following proposition the first result related to the bank's asset composition.

**Proposition 2.** *When the bank is bound by the LR requirement at the group level (i.e.* $ARW^G(w^G, S^G) < \frac{\chi}{\gamma}$*), we have* $w^B < w^G$*.*

*Proof.* See Appendix A.2 □

Proposition 2 states that, when the bank is bound by the LR requirement at the group level, the allocation of constraints down to business units leads to a reduction of the share of the lending business. To get the intuition behind this result, it is useful to compare the FOCs determining $w^G$ and $w^B$. Given that the LR requirement binds at the group level, we have $\lambda_{VaR} = 0$ and $\lambda_{LR} > 0$ in Equation (12). Therefore, the FOC determining $w^G$ can be rewritten as follows:

$$\left[pG'(w^G S^G) - R\right] - \left[F'((1-w^G)S^G) - R\right] = \lambda_{LR}\left(\underbrace{\chi}_{\substack{\text{marginal leverage}\\ \text{cost of lending}}} - \underbrace{\alpha\chi}_{\substack{\text{marginal leverage}\\ \text{cost of repo}}}\right) \tag{14}$$

Under our simple assumption that the risk weigh of the lending business is equal to 1, the ARW of the lending business equals to 1 which is greater than $\frac{\chi}{\gamma}$. The ARW of the repo business is instead zero, so lower than the CRW. From Constraints (7) - (10), we can

[12] It can happen that both constraints bind at the group level at the same time. But given that that case is a knife-edge case, we do not analyse it. The case where no constraints bind is also not interesting. That is because in that case, the bank's optimal investments are the unconstrained optimum which won't be affected by the application level of constraints.

see that when constraints are applied at the business unit level, the RW requirement will bind for the lending business while the binding requirement for the repo business is the LR. Therefore, in Equation (13) we have $\lambda^L_{LR} = 0$ and the FOC characterising $w^B$ becomes:

$$\left[pG'(w^B S^B) - R\right] - \left[F'((1-w^B)S^B) - R\right] = \lambda^L_{VaR}\left[\underbrace{\frac{\partial(\gamma L)}{\partial L}}_{\substack{\text{marginal RW}\\ \text{capital cost of lending}}} - \underbrace{\chi\alpha}_{\substack{\text{marginal leverage}\\ \text{cost of repo}}}\right] \tag{15}$$

Both Equations (14) and (15) equate, on the left-hand side (LHS), the marginal benefit of reallocating investment from repo business to lending business with its marginal cost on the right-hand side (RHS). The former is the increase in the bank's expected marginal profit due to higher profitability of the lending business while the latter is measured in terms of marginal changes in required equity capital. The main differences between the two equations lie in the RHS, indicating that variations in the marginal capital cost drive the divergence between $w^G$ and $w^B$.

We note that the term in the square bracket on the RHS of Equation (14) is smaller than the corresponding term on the RHS of Equation (15) as the lending business faces a higher marginal RW capital cost than its leverage cost. Repo investments become relatively more attractive than lending under business-level application. Therefore, when constraints are applied down, the banking group increases the share of its balance sheet allocated to the repo business.

One important remark is in order. The results described in Proposition 2 may appear to contradict existing literature that finds banks increase their investment in riskier assets following the introduction of a binding LR requirement. The key difference is that Proposition 2 compares the bank's investment policy when subject to both regulatory constraints but applied at different consolidated levels. By contrast, studies such as Kiema and Jokivuolle (2014) and Acosta-Smith, Grill and Lang (2020) compare banks' investments when subject solely to the RW requirement versus both RW and LR requirements. Proposition 2 thus advances the literature by illustrating how the effects of a binding LR requirement, as identified in those studies, may differ when the requirement is imposed at a business level below the group level.

**RW-constrained bank** We now turn to the most analytically interesting case, where the bank is not constrained by the LR at the group level but by the RW requirement. This is equivalent to $ARW^G(w^G, S^G) > \frac{\chi}{\gamma}$.

**Proposition 3.** *When the bank is bound by the RW constraint at the group level (i.e.* $ARW^G(w^G, S^G) > \frac{\chi}{\gamma}$*), it can happen that* $w^B > w^G$

*Proof.* See Appendix A.3 □

Proposition 3 shows that shifting the application of regulatory constraints from the group level to the business unit level can lead an RW-constrained bank to reduce the share of its repo activities in the total balance sheet. The inequality $w^B > w^G$ implies not only a decline in repo investment in absolute terms (i.e. $X^B < X^G$) but also a relative decline compared to the lending business. Therefore, the business unit-level application induces a *disproportionate* reduction in repo investments.

To understand the underlying intuition, it is again helpful to compare the two FOCs that determine $w^G$ and $w^B$. From Equation (12), we have $\lambda_{LR} = 0$ and $\lambda_{VaR} > 0$ when the bank is bound by the RW requirement at the group level. Hence, the FOC determining $w^G$ will now look like as follows:

$$\big[pG'(w^G S^G) - R\big] - \big[F'((1-w^G)S^G) - R\big] = \lambda_{VaR} \left[ \underbrace{\frac{\partial(\gamma L)}{\partial L}}_{\substack{\text{marginal RW} \\ \text{capital cost of lending}}} - \underbrace{0}_{\substack{\text{marginal RW} \\ \text{capital cost of repo}}} \right] \tag{16}$$

When the constraints are allocated down to business units, the binding constraints mirror those in the case of LR-constrained bank. Accordingly, the FOC determining $w^B$ remains as in Equation (15).

Equation (16) also equates the marginal benefit of reallocating one unit of investment from the repo business to the lending business with its marginal cost. Comparing this to Equation (15), we note that under group-level application, the bank's investment decisions are shaped by the difference in the marginal RW capital cost between the two businesses, as the binding constraint at this level is the RW requirement. In contrast, under business unit-level application, the relevant constraints differ: the lending business remains subject to the RW requirement, while the repo business is constrained by the LR requirement. Investment decisions are then driven by the difference between the marginal RW capital cost of lending and the marginal leverage cost of repo. Since the repo unit faces a higher marginal LR cost relative to its RW cost, the bank prefers to allocate a larger share of investment to the lending business when constraints are applied at the business unit level. As a result, the share of repo activities declines under business unit-level application.

**Corollary 1.** *In the case of RW-constrained bank, we have that $w^B - w^G$ is increasing in $\alpha$.*

*Proof.* See Appendix A.4 □

As $\alpha$ captures the specific multiplier of leverage exposure for repo activities due to the regulatory treatment of repo transactions, Corollary 1 highlights that the allocation of regulatory constraints to business units has a stronger impact on the repo business compared to other low-risk activities.

# 4 Generalised framework for calibration

The analytical results from the stylised model demonstrate that the effects of allocating constraints down to business units hinge on which constraints bind at that level, which in turn depend on the ARW of each business. This underscores the importance of assessing the empirical relevance of these theoretical insights. In this section, we will generalise the simple framework to bring it to the data.

## 4.1 Generalised model

**Two business units** We generalize the modeling of the two businesses by assuming that losses in the lending business follow a continuous distribution. Let $\tilde{Z}$ be the random variable that captures losses per unit of lending. Therefore, the bank's ex-post lending revenue is equal to $G(L) - ZL$ where $Z$ is the realised value of $\tilde{Z}$. We assume that $\tilde{Z}$ is distributed according to the distribution $(H_Z, h_Z)$ with expected value equal to $\mu_Z$. We retain the assumption that the repo business is risk-free. However, we relax the earlier normalisation of government bond coupon to zero and, instead, assume it equals $c$. This modification allows us to better capture the profitability of the repo business in the data. Assumption 2 on the profitability rank can now be rewritten as follows:

$$G'(y) - \mu_Z > F'(y) + c \quad \text{for all} \quad y$$

**Regulatory constraints and internal capital allocation** In this generalised model, we do not assume an exogenous risk weight for the lending business; instead, we allow the risk weight to depend on the risk of loans, as captured by the loss random variable $\tilde{Z}$. To do so, we formulate the RW requirement using the Value-at-Risk (VaR) constraint as follows:

$$\mathbb{P}\left(\tilde{\Pi}_L + \Pi_X \leq 0\right) \leq a \tag{17}$$

where $\tilde{\Pi}_L$ and $\Pi_X$ are now given by:

$$\tilde{\Pi}_L = G(L) - \tilde{Z}L - R(L - K_L) \quad \text{and} \quad \Pi_X = F(X) + cX - R(X - K_X)$$

Constraint (17) states that the probability for the total losses of the bank's asset portfolio being higher than its equity capital is lower than $a$. After some algebra, it can be rewritten as [13]:

$$K \geq \frac{VaR_{1-a}(\tilde{Z}L) - \Pi(L, X)}{R} \tag{18}$$

where

$$\Pi(L, X) = G(L) - RL + F(X) + cX - RX$$

In the Basel III framework, the RHS of Constraint (18) is equivalent to the product of the RW capital requirement and the $RWA^G(L, X)$. $RWA^G(L, X)$ can thus be proxied in our generalised model by:

$$RWA^G(L, X) = \frac{VaR_{1-a}(\tilde{Z}L) - \Pi(L, X)}{\gamma R}$$

The LR requirement at the group level is as before:

$$K \geq \chi(L + \alpha X) \tag{19}$$

[13] See Appendix A.5 for the detailed derivation.

When the bank chooses to allocate regulatory constraints down to its business units, the two constraints for each business unit are given by:

$$\mathbb{P}\left(\tilde{\Pi}_L \leq 0\right) \leq a \quad \text{and} \quad K_L \geq \chi L$$

for the lending business and,

$$K_X \geq 0 \quad \text{and} \quad K_X \geq \chi \alpha X$$

for the repo business. The individual VaR constraint for the lending business can similarly be expressed in terms of $RWA^L(L)$ as follows:

$$K_L \geq \gamma RWA^L(L) \quad \text{where} \quad RWA^L(L) = \frac{VaR_{1-a}(\tilde{Z}L) - (G(L) - RL)}{\gamma R} \tag{20}$$

## 4.2 Analytical derivation

In this section, we characterise analytically the bank's optimal investments in the generalised model. Similarly to Section 3, we will compare the bank's optimal choice of $w$ between the case where the two constraints are applied at the group level and the case in which both business units have to individually comply with both regulatory constraints.

The bank's expected profit is now given by:

$$\mathbb{E}\left(\tilde{\Pi}_L + \Pi_X\right) = G(wS) - \mu_Z wS + F((1-w)S) + c(1-w)S - RS + RK$$

The LR constraints at the group and business-unit levels retain the same form as, respectively, Constraint (6) and Constraints (9) - (10). The RW constraints are now expressed as follows:

$$K \geq \gamma RWA^G(w,S) = \frac{VaR_{1-a}(\tilde{Z}w)S - \Pi(w,S)}{R} \tag{21}$$

for the group level and

$$K_L \geq \gamma RWA^L(w,S) = \frac{VaR_{1-a}(\tilde{Z}w)S - (G(wS) - RwS)}{R} \quad (22)$$

$$K_X \geq 0 \quad (23)$$

for the business-unit level.

In line with the simplified model, the group-level LR constraint is weakly looser than business unit-level LR constraints. The group-level RW constraint is also looser than the business unit-level constraints and the gap can be expressed in terms of $Div$ defined as follows:

$$Div = F\left((1-w)S\right) + c(1-w)S - R(1-w)S \quad (24)$$

$Div$ represents the diversification benefit per unit of size to the bank if it applies the RW constraint at the group level. Therefore, the result related to the total size of the bank's balance sheet is the same as the one in Proposition 1.

As for the bank's asset composition, we note that in this generalised setting, the ARW of the banking group and the lending unit depends explicitly on the riskiness of the lending business. Specifically, the ARW of the banking group - $ARW^G$ - can be computed as:

$$ARW^G(w,S) = \frac{\frac{VaR_{1-a}(\tilde{Z}w)S - \Pi(w,S)}{\gamma R}}{wS + \alpha(1-w)S}$$

while the ARW of the lending unit is calculated as:

$$ARW^L(w,S) = \frac{\frac{VaR_{1-a}(\tilde{Z}w)S - (G(wS) - RwS)}{R}}{wS}$$

The following proposition describes the bank's optimal investments for the two cases of LR-constrained and RW-constrained bank in our generalised model.

**Proposition 4.** *In the generalised setting, the bank's optimal investments are characterised as follows:*

1. *When the bank is bound by the LR requirement at the group level (i.e. $ARW^G(w^G, S^G) < \frac{\chi}{\gamma}$), we have:*
   (a) $w^B = w^G$ *if* $ARW^L < \frac{\chi}{\gamma}$
   (b) $w^B < w^G$ *if* $ARW^L > \frac{\chi}{\gamma}$
2. *When the bank is bound by the RW constraint at the group level (i.e. $ARW^G(w^G, S^G) > \frac{\chi}{\gamma}$), it can happen that $w^B > w^G$ if the following conditions are satisfied:*
   (a) $ARW^L \geq \frac{\chi}{\gamma}$
   (b) $\frac{\partial Div}{\partial w} < 0$

*Proof.* See Appendix A.6 □

The first part of Proposition 4 generalises Proposition 2 by allowing for the cases where the riskiness of the lending business is not too high (i.e. $ARW^L < \frac{\chi}{\gamma}$). In such cases, applying regulatory constraints at the business unit level does not alter the asset composition of the LR-constrained bank. That is because the binding constraint for the lending unit on a stand-alone basis is also the LR, which leads to the following FOC for $w^B$:

$$\left[G'(w^B S^B) - \mu_Z - R\right] - \left[F'((1 - w^B)S^B) + c - R\right] = \lambda_{LR}^L \left( \underbrace{\chi}_{\substack{\text{marginal leverage} \\ \text{cost of lending}}} - \underbrace{\alpha\chi}_{\substack{\text{marginal leverage} \\ \text{cost of repo}}} \right) \tag{25}$$

Hence, $w^B$ is determined by the difference in the marginal leverage costs between the two business units, similar to $w^G$.

The second part of Proposition 4, relative to Proposition 3, shows that endogenising the risk weight of the lending business clarifies how diversification benefits affect the impact of the allocation of regulatory constraints on the bank's asset composition when it is bound by the RW requirement at the group level. This is made clear by comparing the FOCs charaterising $w^G$:

$$\left[G'(w^G S^G) - \mu_Z - R\right] - \left[F'((1-w^G)S^G) + c - R\right] = \lambda_{VaR}\left[\underbrace{\frac{\partial(\gamma RWA^L)}{\partial L}}_{\substack{\text{marginal RW}\\ \text{capital cost of lending}}} - \underbrace{0}_{\substack{\text{marginal RW}\\ \text{capital cost of repo}}} - \frac{\partial Div}{\partial w}\right] \tag{26}$$

and $w^B$:

$$\left[G'(w^B S^B) - \mu_Z - R\right] - \left[F'((1-w^B)S^B) + c - R\right] = \lambda^L_{VaR}\left[\underbrace{\frac{\partial(\gamma RWA^L)}{\partial L}}_{\substack{\text{marginal RW}\\ \text{capital cost of lending}}} - \underbrace{\chi\alpha}_{\substack{\text{marginal leverage}\\ \text{cost of repo}}}\right] \tag{27}$$

# 5 Model calibration and numerical simulation

## 5.1 Model calibration

In this section, we calibrate our generalised model using data for banks in the UK to verify the empirical relevance of our analytical findings. We first set out additional parametric assumptions that we make to take the model to the data. We then describe the data used and explain our calibration procedure.

**Parametric assumptions** The bank's ex-ante gross interest income from loans $G(L)$ is the product of the loan volume $L$ and the gross interest rate charged on loans. We assume that the interest rate is a decreasing function of the loan volume: $g_1 + g_2 L$ where $g_1 > 0$ and $g_2 < 0$. Therefore, we have:

$$G(L) = (g_1 + g_2 L)L$$

In line with the literature, we also assume that the losses per unit of loans $\tilde{Z}$ are log-normally distributed with parameter $\mu_Z^{log}$ and $\sigma_Z^{log}$.

For the repo market, we focus on market-making for repo and reverse repo transactions secured against UK government bonds. This in turn has two implications. First, $F(X)$ will be the revenue from reverse repo activities net of repo funding cost. We assume that the interest rates charged on both repos and reverse repos depend on the transactional amount, which implies that $F(X)$ can be written as:

$$F(X) = \underbrace{(d_1 + \varepsilon_1 X)X}_{\text{reverse repo revenue}} - \underbrace{(d_2 + \varepsilon_2 X)X}_{\text{repo cost}}.$$

We further denote $\beta_1 = d_1 - d_2$ and $\beta_2 = \varepsilon_1 - \varepsilon_2$ where $\beta_1 > 0$ and $\beta_2 < 0$. Second, we assume that the repo business is riskless. Table 1 summarises the set of parameters that need to be calibrated.

**Data** To calibrate the model, we use three main data sources. We first retrieve daily yield rates for the 15-year UK government bond retrieved from Factset. Second, we collect semi-annual data on performance analysis, asset quality and balance sheet of 15 UK banks from 2015 to 2018 retrieved from S&P Market Intelligence (S&P MI). Our last source of data is the confidential Sterling Money Market Data (SMMD) of the Bank of England. It contains daily, transactional level data on repo and reverse repo transactions with a maturity of up to one year that are denominated in GBP and secured against UK government-issued securities (gilts), covering 95% of the total market turnover. Internet Appendix Table B.1

Table 1: Parameters to be calibrated

| Parameters | Description |
|---|---|
| $a$ | VaR confidence level |
| $\chi$ | Leverage ratio requirement |
| $c$ | Coupon on government bond |
| $R$ | Bank's borrowing cost |
| $g_1$ | Marginal return on loan |
| $g_2$ | Curvature of loan return |
| $\mu_Z^{log}$ | Lognormal parameter of loan losses |
| $\sigma_Z^{log}$ | Lognormal parameter of loan losses |
| $\beta_1$ | Marginal return on repo |
| $\beta_2$ | Curvature of return on repo |

reports the variables that we use in these datasets for our calibration.

**Calibration methods** We set a series of parameters individually. We set the VaR confidence level $a$ at 0.001 and the minimum leverage ratio $\chi$ equal to 3%, which correspond to the Basel III requirements. We proxy the coupon on government bonds with the 15Y UK gilt yield, as the average of daily yields over the entire period. We set the bank's borrowing cost $R$ to be the average cost of funds of all banks in our sample.

We estimate the distribution parameters $\mu_Z^{log}$ and $\sigma_Z^{log}$ of lending losses corresponding to the random variable $\tilde{Z}$ by defining the realised value as the amount of impaired loans per unit of total loans. Then we use the maximum likelihood estimation to fit the lognormal distribution of $\tilde{Z}$ with the distribution of impaired loans.

We employ the least square fitting method to derive parameters $g_1$ and $g_2$ that determine how the net interest margin depends on the gross lending. To do so, we first express the net interest margin $IM_{it}$ of bank $i$ at time $t$ as:

$$IM_{it} = g_1 + g_2 L_{i,t} - Z_{it} - R_{it}$$

where $L_{it}$ denotes gross loans to customers; $Z_{it}$ is the realised value of impaired loans to total loans and $R_{it}$ is the cost of funds, where all the variables are observed in the data. $g_1$ and $g_2$ then can be obtained by estimating the following regression equation:

$$y_{i,t} = g_1 + g_2 L_{i,t} + \eta_{i,t}$$

where $y_{i,t} = IM_{i,t} + Z_{i,t} + R_{i,t}$ and $\eta_{i,t}$ is error term. Both coefficients $g_1, g_2$ derived from the regression are statistically significant at, respectively, 1% and 5% level.

We then estimate the repo income by regressing the repo $f_{ijt}^{repo}$ and reverse repo interest rate $f_{ijt}^{reverse}$ reported for each transaction $j$ entered by dealer bank $i$ at time $t$ on the borrowing amount of that transaction using the equations:

$$f_{ijt}^{reverse} = d_1 + \varepsilon_1 X_{ijt}^{reverse} + \nu_{ijt} \quad \text{and} \quad f_{ijt}^{repo} = d_2 + \varepsilon_2 X_{ijt}^{repo} + \upsilon_{ijt}$$

Both regressions give statistically significant coefficients at 1% level. Next, we calculate the marginal return on repo $\beta_1$ as equal to $d_1 - d_2$ and the curvature of repo returns $\beta_2$ as $\varepsilon_1 - \varepsilon_2$. Table 2 reports the calibrated value for all parameters, and Appendix B characterises in more detail the calibrated features of the two units.[14]

## 5.2 Numerical simulations

We solve numerically the two optimisation problems $\wp^G$ and $\wp^B$ for different values of the bank's initial equity $K$ and the calibrated parameter values. Note that depending on the value of $K$, the bank can be bound at the group level either by both LR and RW constraints or only by the RW constraint. Figure 1 compares the bank's optimal investments between the case where both constraints are applied at the group level and the case in which both business units have to comply with both constraints individually, with additional details

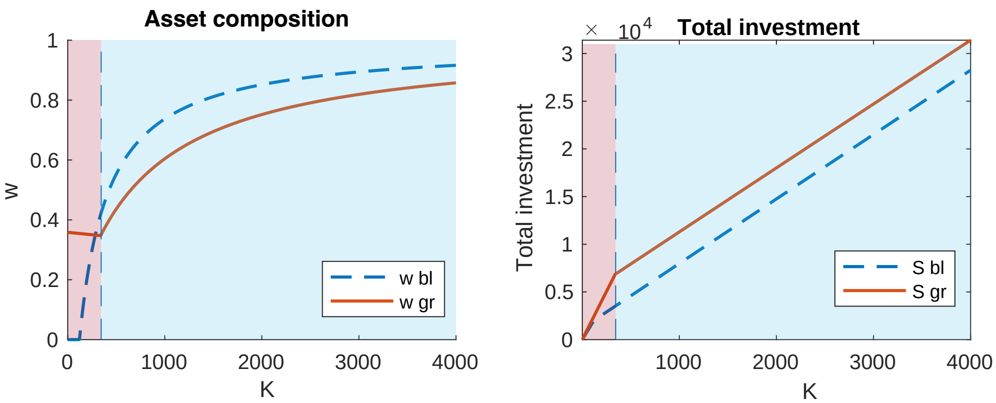
[14]Parameter values are reported, when appropriate, in GBP billion.

Table 2: Calibration to UK Banks

| Description | Parameters | Calibrated Value |
|---|---|---|
| VaR confidence level | a | 0.001 |
| Leverage requirement | $\chi$ | 0.03 |
| Coupon on government bond | $c$ | 1.0172 |
| Bank's borrowing cost | $R$ | 1.0114 |
| **Lending unit** | | |
| Marginal return on loan | $g_1$ | 1.0356 |
| Curvature of loan return | $g_2$ | $-2.22 \cdot 10^{-5}$ |
| Log-normal parameter of $Z$ | $\mu_Z^{log}$ | -4.568 |
| (Mean Z) | | (0.015) |
| Log-normal parameter of $Z$ | $\sigma_Z^{log}$ | 0.913 |
| (Standard deviation Z) | | (0.018) |
| **Repo unit** | | |
| Marginal return on repo business | $\beta_1$ | 0.000427 |
| Diminishing return parameter | $\beta_2$ | $-6.943 \cdot 10^{-4}$ |

presented in the Internet Appendix B.

Figure 1: The Bank's Optimal Investments




Note: This figure compares the bank's optimal investments in two cases:(i) when both regulatory constraints are applied at the group level and (ii) when the bank allocates both constraints down to its business units. The red solid lines represent the bank choices for (i), while the blue dashed lines stand for the bank choices under (ii). The dark pink area corresponds to the situation where both LR and RW constraints bind at the group level while in the light blue area, only RW constrain binds at the group level.

The allocation of constraints to business units leads to a smaller bank's balance sheet size as total investment is reduced. The left panel of Figure 1 shows the impact on the asset portfolio. Requiring each unit to comply with both constraints when only the RW constraint binds at the group level (light blue area) leads to a disproportional decrease in the bank's repo business. These numerical results are consistent with the analytical findings described in the previous sections.

### 5.3 Role of business model

As highlighted in the analytical part, the impact of the allocation of constraints on banks' investment decisions depends on the risk profile of their businesses. Hence, we expect that this impact can vary with the banks' business model. To test this hypothesis, we classify the 15 UK banks in our sample in retail and wholesale funded banks following the methodology proposed in Roengpitya et al. (2014). For our setup, the key difference will be in their lending business characteristics and funding costs. Then we recalibrate the lending business while keeping the repo business unchanged, and run numerical simulations.[15]

**Business model classification and calibration** Our business model classification builds on Roengpitya et al. (2014). They use a statistical clustering method based on banks' balance sheet ratios that are informative of their business models. The paper finds that retail-funded banks have a high share of gross loans and rely more on deposits as stable sources of funding. The wholesale-funded banks rely less on deposits, and have relatively more inter-bank liabilities compared to retail banks. Lastly, capital markets-orientated banks have a much higher percentage of trading assets and liabilities compared to the previous two. The last type of bank has the highest ratio of inter-bank borrowing as a percentage of total assets and also displays a lower reliance on stable funding. The paper reports average values of these ratios to total assets, and we use them as a benchmark to construct the selection

[15] Due to repo data confidentiality requirements we cannot split the repo dealer banks into different business models.

criteria for our sample.

Based on their methodology, we split our sample into nine retail and six wholesale banks. Details on the criteria used and business model descriptives can be found in Internet Appendix B. We recalibrate the model to the two bank types and we find that wholesale banks have lower costs of funding, while retail banks have higher marginal returns on lending, as summarised in Table 3.

Table 3: Calibration Across Business Models

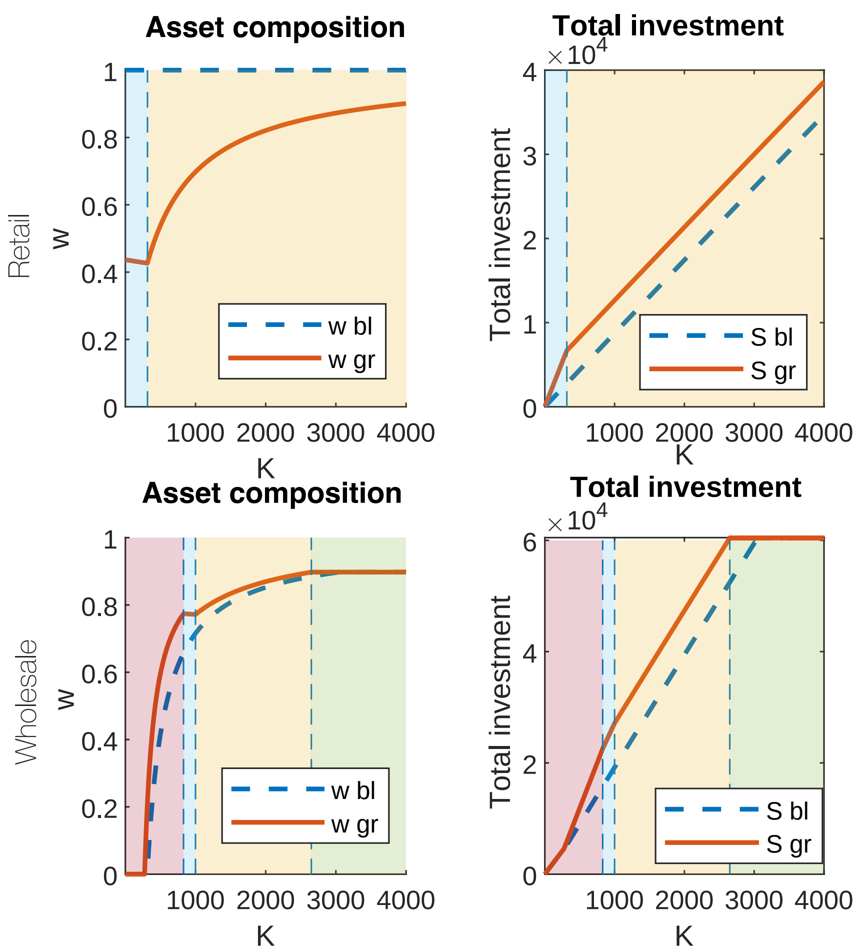
| Description | Parameters | **Retail** | **Wholesale** |
|---|---|---|---|
| Bank's borrowing cost | R | 0.0129 | 0.009 |
| | **Lending** | | |
| Marginal return on loan | $g_1$ | 1.0369 | 1.03081 |
| Curvature of loan return | $g_2$ | $-3.15 \cdot 10^{-5}$ | $-1.03 \cdot 10^{-5}$ |
| Log-normal parameter of Z | $\mu_Z^{log}$ | -4.885 | -3.97 |
| (Mean Z) | | (0.0118) | (0.0207) |
| Log-normal parameter of Z | $\sigma_Z^{log}$ | 0.945 | 0.429 |
| (Standard deviation Z) | | (0.0142) | (0.0093) |

**Numerical simulations for different business models** Figure 2 compares the optimal investments of retail and wholesale banks when both constraints are applied at the group level and when they are allocated down to business units.

Two observations are in order. First, note that the leverage constraint binds at the group level only for wholesale banks, but not for retail banks. This is consistent with the view that financial intermediaries in safe assets are penalised much more by the leverage ratio compared to banks that do not engage in such activities. In our simulation, the Average Risk Weight for the repo business is lower than the Critical Risk Weight which is equal to 0.35. At the same time, the average risk weight dominates the lending business for both bank types, but the diversification benefits of wholesale banks are higher than those of retail banks. This combination can make the LR binding at group level for wholesale banks.

Second, there is a stark difference in the bank's asset allocation between retail and wholesale banks when only the RW constraint binds at the group level (beige area in Figure 2). Precisely, in this case, while the allocation of constraints reduces the repo intermediation of retail banks, it brings about an increase in repo activities for wholesale banks.

Figure 2: Optimal Investments: A Business Model Comparison




Note: This figure compares the optimal investments of retail banks (first row) and wholesale banks (second row) in two cases: (i) both regulatory constraints are applied at the group level and (ii) banks allocate both constraints to its business units. The red solid lines represent the banks' choices in the first case while the blue dashed lines stand for the banks' choices in the second case. The dark pink area corresponds to the case where only the LR constraint binds at the group level; the light blue area to the case in which both LR and RW constraints bind; the beige area to the case where only RW constraint binds and finally the green area is when no constraints bind.

# 6 Discussion and Conclusion

Our paper explains how the LR requirement can adversely affect the repo activities of banks that are seemingly not bound by it. The mechanism we explore operates through banks' internal capital allocation practices - specifically, how they incorporate regulatory constraints when determining the equity capital assigned to each business unit. In a model of a banking group engaged in both lending and repo activities, we show analytically that when equity is allocated based on the most stringent of the applicable regulatory requirements - effectively applying the LR and risk-weighted (RW) constraints at the business-unit level - the LR induces RW-constrained banks to disproportionately reduce their repo activities relative to lending. Calibrating the model confirms this result: even for banks not bound by the LR at the group level, internal allocation of regulatory constraints leads to lower repo intermediation, consistent with our analytical findings.

In this analysis, we do not explicitly model the frictions that justify prudential regulations and therefore do not address normative questions such as the optimality of the LR. Instead, we take a positive approach, highlighting a potential unintended consequence of this regulation. The LR is designed as a non-risk-based backstop to the RW requirement. Because of its risk-insensitive nature, it is expected to curb excessive leverage by limiting banks' investments in both high- and low-risk activities. At the same time, its backstop role implies an expectation of minimal impact on low-risk activities when banks are not constrained by the requirement. Our findings suggest that this expectation may not hold under certain internal capital allocation practices, which can lead to greater-than-anticipated reductions in banks' capacity to intermediate in key markets - such as repo and government bonds - with possible adverse implications for market functioning.

# References

**Acosta-Smith, Jonathan, Michael Grill, and Jan Hannes Lang**, "The Leverage Ratio, Risk-Taking and Bank Stability," *Journal of Financial Stability*, 2020, *Article nr. 100833.*

**Allahrakha, Meraj, Jill Cetina, and Benjamin Munyan**, "Do higher capital standards always reduce bank risk? The impact of the Basel leverage ratio on the US triparty repo market," *Journal of Financial Intermediation*, 2018, *34*, 3–16.

**Anbil, Sriya and Zeynep Senyuz**, "How has monetary and regulatory policy affected trading relationships in the US repo market," *International Journal of Central Banking*, 2022, *18* (4), 1–52.

**Anderson, Christopher S., David C. McArthur, and Ke Wang**, "Internal risk limits of dealers and corporate bond market making," *Journal of Banking and Finance*, 2023, *147*, Article nr. 106653.

**Bajaj, Rasna, Andrew Binmore, Rupak Dasgupta, and Quynh-Anh Vo**, "Banks internal capital markets: how do banks allocate capital internally?," *Bank of England Quarterly Bulletin Q2*, 2018.

**Barbiero, Omar, Falk Bräuning, Gustavo Joaquim, and Hillary Stein**, "Dealer risk limits and currency returns," *Available at SSRN 4728116*, 2024.

**Bassi, Claudio, Markus Behn, Michael Grill, and Martin Waibel**, "Window dressing of regulatory metrics: evidence from repo markets," *Journal of Financial Intermediation*, 2024, *58*, 101086.

**Bicu-Lieb, Andreea, Louisa Chen, and David Elliott**, "The Leverage Ratio and Liquidity in the Gilt and Gilt Repo Markets," *Journal of Financial Markets*, 2020, *48*, Article nr. 100510.

**Blum, Jürg M**, "Why Basel II may need a leverage ratio restriction," *Journal of Banking & Finance*, 2008, *32* (8), 1699–1707.

**Bowman, Michelle W.**, "Unintended Policy Shifts and Unexpected Consequences," Speech, Board of Governors of the Federal Reserve System June 2025. Last updated June 23, 2025.

**Bräuning, Falk and Hillary Stein**, "The effect of primary dealer constraints on intermediation in the Treasury market," *Available at SSRN 4862212*, 2025.

**Breckenfelder, Johannes and Victoria Ivashina**, "Bank balance sheet constraints and bond liquidity," *ECB Working Paper*, 2021.

**Cenedese, Gino, Pasquale Della Corte, and Tianyu Wang**, "Currency mispricing and dealer balance sheets," *The Journal of Finance*, 2021, *76* (6), 2763–2803.

**Choi, Dong Beom, Michael R Holcomb, and Donald P Morgan**, "Bank leverage limits and regulatory arbitrage: Old question - New evidence," *Journal of Money, Credit and Banking*, 2020, *52* (S1), 241–266.

**Committee on the Global Financial System**, "Repo market functioning report," *Bank for International Settlements*, 2017, *no 59.*

**Duffie, Darrell**, "Financial Regulatory Reform After the Crisis: An Assessment," *Management Science*, 2017, *64* (10), 4835–4857.

**Favara, Giovanni, Sebastian Infante, and Marcelo Rezende**, "Leverage regulations and Treasury market participation: Evidence from credit line drawdowns," *Available at SSRN 4175429*, 2024.

**Gambacorta, Leonardo and Sudipto Karmakar**, "Leverage and Risk-Weighted Capital Requirements," *International Journal of Central Banking*, 2018, *14* (5), 153–191.

**Gerba, Eddie and Petros Katsoulis**, "The repo market under Basel III: Effects of capital and liquidity regulations on market fragmentation," *International Journal of Finance & Economics*, 2025, *30* (3), 2724–2744.

**Giannetti, Mariassunta, Chotibhak Jotikasthira, Andreas C Rapp, and Martin Waibel**, "Intermediary Balance Sheet Constraints, Bond Mutual Funds' Strategies, and Bond Returns," *Swedish House of Finance Research Paper*, 2024, (23-10), 23–19.

**Goel, Tirupam, Ulf Lewrick, and Nikola Tarashev**, "Bank capital allocation under multiple constraints," *Journal of Financial Intermediation*, 2020, *44*, Article nr. 100844.

**Haynes, Richard and Lihong McPhail**, "When leverage ratio meets derivatives: Running out of options?," *Financial Markets, Institutions & Instruments*, 2021, *30* (5), 201–224.

**He, Zhiguo, Stefan Nagel, and Zhaogang Song**, "Treasury inconvenience yields during the COVID-19 crisis," *Journal of Financial Economics*, 2022, *143* (1), 57–79.

**Hüser, Anne-Caroline, Caterina Lepore, and Luitgard Anna Maria Veraart**, "How does the repo market behave under stress? Evidence from the COVID-19 crisis," *Journal of Financial Stability*, 2024, *70*, 101193.

**Khaykin, Ilya, Ugur Koyluoglu, Douglas Elliott, and Christopher Spicer**, "Balancing complex and competing constraints on capital, liquidity and funding," *Oliver Wyman. Financial Resource Management. Technical report.*, 2017.

**Kiema, Ilkka and Esa Jokivuolle**, "Does a leverage ratio requirement increase bank stability?," *Journal of Banking & Finance*, 2014, *39*, 240–254.

**Kotidis, Antonis and Neeltje Van Horen**, "Repo market functioning: The role of capital regulation," *CEPR Discussion Paper No. DP13090*, 2019.

**Krüger, Philipp, Augustin Landier, and David Thesmar**, "The WACC fallacy: The real effects of using a unique discount rate," *The Journal of Finance*, 2015, *70* (3), 1253–1285.

**Li, Dan, Lubomir Petrasek, and Mary H Tian**, "Risk-averse Dealers in a Risk-free Market–The Role of Internal Risk Limits," *Available at SSRN 4824250*, 2024.

**Lopes, Samuel Da Rocha, Daniel Foos, Aaron Janowski, Stefan Schmitz, Mariana Tomova, and Julieta Yung**, "Bank capital and balance sheet management during times of distress: international evidence," Technical Report Working Paper 46, Basel Committee on Banking Supervision 2025.

**Lu, Lina and Jonathan Wallen**, "What Do Bank Trading Desks Do?," *Harvard Working Paper*, 2024.

**_ , Marco Macchiavelli, and Jonathan Wallen**, "Internal and External Capital Markets of Large Banks," *Available at SSRN 4660712*, 2023.

**Perold, Andre F**, "Capital allocation in financial firms," *Journal of Applied Corporate Finance*, 2005, *17* (3), 110–118.

**Roengpitya, Rungporn, Nikola A Tarashev, and Kostas Tsatsaronis**, "Bank business models," *BIS Quarterly Review December*, 2014.

# Appendix

## A Analytical Proofs

### A.1 Derivation of the first order conditions (FOCs) for Problems $\wp^G$ and $\wp^B$

The Lagrangian for Problem $\wp^G$ reads:

$$\Lambda_g = \quad pG(wS) + F\left((1-w)S\right) - RS + RK + \lambda_{VaR}\left(K - \gamma wS\right) + \lambda_{LR}(K - \chi\big(w + \alpha(1-w)\big)S)$$

where $\lambda_{VaR}$ and $\lambda_{LR}$ are the Lagrange multiplier for, respectively, the group-level RW constraint and the group-level LR constraint. The FOC that determines $w^G$ is as follows:

$$pG'(wS)S - F'\left((1-w)S\right)S - \lambda_{VaR}\gamma S - \lambda_{LR}\chi(1-\alpha)S = 0$$

which can be rearranged as:

$$[pG'(wS) - R] - [F'\left((1-w)S\right) - R] = \lambda_{VaR}\gamma + \lambda_{LR}\chi(1-\alpha) \tag{A.1}$$

Similarly, the Lagrangian for Problem $\wp^B$ reads:

$$\begin{aligned}\Lambda_b = \quad & pG(wS) + F\left((1-w)S\right) - RS + RK + \lambda^L_{VaR}\left(K_L - \gamma wS\right) + \lambda^L_{LR}(K_L - \chi wS) \\ & + \lambda^X_{VaR}(K_X - 0) + \lambda^X_{LR}(K_X - \chi\alpha(1-w)S) + \lambda_K(K - K_L - K_X)\end{aligned}$$

where $\lambda^L_{VaR}, \lambda^X_{VaR}, \lambda^L_{LR}, \lambda^X_{LR}$ and $\lambda_K$ are the Lagrange multipliers of corresponding constraints. The FOC for $w^B$ is written as follows:

$$pG'(wS) - F'\left((1-w)S\right) - \lambda^L_{VaR}\gamma S - \lambda^L_{LR}\chi S + \lambda^X_{LR}\chi\alpha S = 0$$

After rearranging, we obtain:

$$[pG'(wS) - R] - [F'((1-w)S) - R] = \lambda^L_{VaR}\gamma + \lambda^L_{LR}\chi - \lambda^X_{LR}\chi\alpha \tag{A.2}$$

## A.2 Proof of Proposition 2

When the LR requirement is the binding constraint at the group level, we have $\lambda_{VaR} = 0$ and $\lambda_{LR} \geq 0$. Therefore, based on Equation (A.1), we see that in this case, $w^G$ is determined by the following equation:

$$[pG'(wS) - R] - [F'((1-w)S) - R] = \lambda_{LR}(\chi - \alpha\chi) \tag{A.3}$$

In relation to $w^B$, given that the RW requirement binds for the lending business and the binding requirement for the repo business is the LR, we have $\lambda^L_{LR} = \lambda^X_{VaR} = 0$. Moreover, based on the Lagrangian for Problem $\wp^B$ explained in Appendix A.1, the two FOCs for $K_L$ and $K_X$ are as follows:

$$\lambda^L_{VaR} + \lambda^L_{LR} - \lambda_K = 0 \quad \text{and} \quad \lambda^X_{VaR} + \lambda^X_{LR} - \lambda_K = 0$$

which means:

$$\lambda^L_{VaR} + \lambda^L_{LR} = \lambda^X_{VaR} + \lambda^X_{LR} = \lambda_K$$

Since $\lambda^L_{LR} = \lambda^X_{VaR} = 0$, we obtain $\lambda^L_{VaR} = \lambda^X_{LR}$. The FOC (A.2) therefore can be written as follows:

$$[pG'(wS) - R] - [F'((1-w)S) - R] = \lambda^L_{VaR}(\gamma - \chi\alpha) \tag{A.4}$$

Note that the LHS of Equations (A.3) and (A.4) is a decreasing function of $w$. Moreover, since $\gamma > \chi$, it can happen that the RHS of Equation (A.3) is smaller than that of Equation (A.4). These all together imply that $w^G > w^B$.

## A.3 Proof of Proposition 3

In the case where the RW requirement is the binding constraint at the group level, we have $\lambda_{LR} = 0$ and $\lambda_{VaR} \geq 0$. Therefore, based on Equation (A.1), we see that in this case, $w^G$ is determined by the following equation:

$$[pG'(wS) - R] - [F'((1-w)S) - R] = \lambda_{VaR}\gamma \tag{A.5}$$

When the constraints are allocated down to business units, the binding constraints mirror those in the case of the LR-constrained bank. Therefore, the FOC characterising $w^B$ remains as in Equation (A.4). Since the RHS of Equation (A.5) is greater than that of Equation (A.4), we have $w^G < w^B$.

## A.4 Proof of Corollary 1

From Appendix A.3, we see that $w^G$ is determined by Equation (A.5) while $w^B$ is characterised by Equation (A.4). Since the RHS of Equation (A.4) is decreasing with $\alpha$, we obtain that $w^B$ is increasing with $\alpha$ but $w^G$ does not depend on it. Therefore, $w^B - w^G$ is increasing in $\alpha$.

## A.5 Derivation of Constraint (18) - the RW constraint at the group level in the generalised model

Given that

$$\tilde{\Pi}_L = G(L) - \tilde{Z}L - R(L - K_L)$$

and

$$\Pi_X = F(X) + cX - R(X - K_X)$$

we can write $\mathbb{P}\left(\tilde{\Pi}_L + \Pi_X \leq 0\right) \leq a$ as:

$$\mathbb{P}\Big(G(L) + F(X) + cX - R(X + L - K) \leq \tilde{Z}L\Big) \leq a \tag{A.6}$$

Using Value at Risk definition, Inequality (A.6) is equivalent to

$$VaR_{1-a}(\tilde{Z}L) \leq G(L) + F(X) + cX - R(X + L - K)$$

or

$$K \geq \frac{VaR_{1-a}(\tilde{Z}L) - [G(L) - RL + F(X) + cX - RX]}{R} \tag{A.7}$$

## A.6 Proof of Proposition 4

In the generalised model, Problem $\wp^G$ can be written as follows:

$$\underset{S,w}{\text{Max}} \quad \{\Pi(w, S) - \mu_Z wS + RK\}$$

subject to

$$K \geq \gamma RWA^G(w, S) = \frac{VaR_{1-a}(\tilde{Z}w)S - \Pi(w, S)}{R} \tag{A.8}$$

$$K \geq \chi\,(wS + \alpha(1 - w)S) \tag{A.9}$$

while Problem $\wp^B$ is given by:

$$\underset{S,w}{\text{Max}} \quad \{\Pi(w, S) - \mu_Z wS + RK\}$$

subject to

$$K_L \geq \gamma RWA^L(w, S) = \frac{VaR_{1-a}(\tilde{Z}w)S - (G(wS) - RwS)}{R} \tag{A.10}$$

$$K_X \geq \gamma RWA^X(w, S) = 0 \tag{A.11}$$

$$K_L \geq \chi wS \tag{A.12}$$

$$K_X \geq \chi\alpha(1 - w)S \tag{A.13}$$

$$K \geq K_L + K_X \tag{A.14}$$

**Part 1(a):** We will establish that the solution $(w^G, S^G)$ to Problem $\wp^G$ will also be the solution to Problem $\wp^B$ if the following two conditions are satisfied:

$$\chi(wS + \alpha(1-w)S) > \gamma RWA^G \tag{A.15}$$

as well as

$$ARW^L(w,S) = \frac{RWA^L(w,S)}{wS} \leq \frac{\chi}{\gamma} \tag{A.16}$$

Indeed, since $(w^G, S^G)$ is the solution to Problem $\wp^G$ when Condition (A.15) is satisfied, we have:

$$K = \chi(w^G S^G + \alpha(1-w^G)S^G) \tag{A.17}$$

When Condition (A.16) hold, the relevant constraints for Problem $\wp^B$ will be Constraints (A.12), (A.13) and (A.14). Clearly, $(w^G, S^G)$ that satisfies Equality (A.17) will also satisfy all Constraints (A.12), (A.13) and (A.14) where we simply choose $K_L = \chi w^G S^G$ and $K_X = \chi\alpha(1-w^G)S^G$. This in turn implies that $(w^G, S^G)$ belong to the feasible set of Problem $\wp^B$. Since the feasible set of Problem $\wp^B$ is smaller than that of Problem $\wp^G$, $(w^G, S^G)$ are also the solution to Problem $\wp^B$.

**Part 1(b):** The proof is similar to the proof of Proposition 2

**Part 2:** The Lagrangian for Problem $\wp^G$ reads:

$$\begin{aligned}\Lambda_g = \quad & \Pi(w,S) - \mu_Z wS + RK + \lambda_{VaR}\Big(K - \frac{VaR_{1-a}(\tilde{Z}w)S - \Pi(w,S)}{R}\Big) \\ & + \lambda_{LR}(K - \chi\big(w + \alpha(1-w)\big)S)\end{aligned}$$

The FOC that determines $w^G$ is as follows:

$$\frac{\partial \Pi(S,w)}{\partial w} - \mu_Z S - \lambda_{VaR}\frac{\partial(\gamma RWA^G(w,S))}{\partial w} - \lambda_{LR}\chi(1-\alpha)S = 0 \tag{A.18}$$

Since the bank is bound by the RW constraint at the group level, we have $\lambda_{LR} = 0$ and

$\lambda_{VaR} \geq 0$. $w^G$ is thus characterised by the following equation:

$$\left[G'(w^G S^G) - \mu_Z - R\right] - \left[F'((1-w^G)S^G) + c - R\right] = \lambda_{VaR}\left[\frac{\partial(\gamma RWA^L)}{\partial L} - 0 - \frac{\partial Div}{\partial w}\right] \quad \text{(A.19)}$$

Now, we will derive the FOC characterising $w^B$. The Lagrangian for Problem $\wp^B$ reads:

$$\begin{aligned}\Lambda_b = \quad & \Pi(S,w) - \mu_Z wS - \mu_\varepsilon(1-w)S + RK + \lambda^L_{VaR}\Big(K_L - \frac{VaR_{1-a}(\tilde{Z}w)S - G(wS) + RwS}{R}\Big) \\ & + \lambda^X_{VaR}\Big(K_X - 0\Big) + \lambda^L_{LR}(K_L - \chi wS) + \lambda^X_{LR}(K_X - \chi\alpha(1-w)S) + \lambda_K(K - K_L - K_X)\end{aligned}$$

The FOC for $w^B$ is written as follows:

$$\frac{\partial \Pi(S,w)}{\partial w} - \mu_Z S - \lambda^L_{VaR}\frac{\partial(\gamma RWA^L(w,S))}{\partial w} - \lambda^L_{LR}\chi S + \lambda^X_{LR}\chi\alpha S = 0$$

Under Condition $ARW^L > \frac{\chi}{\gamma}$, the binding constraints in Problem $\wp^B$ will thus be Constraints (A.10) and (A.13), which implies $\lambda^L_{LR} = 0$ and $\lambda^X_{VaR} = 0$. As we have $\lambda^L_{VaR} = \lambda^X_{LR} \geq 0$, $w^B$ is determined as follows:

$$\left[G'(w^B S^B) - \mu_Z - R\right] - \left[F'((1-w^B)S^B) + c - R\right] = \lambda^L_{VaR}\left[\frac{\partial(\gamma RWA^L)}{\partial L} - \chi\alpha\right] \quad \text{(A.20)}$$

Therefore, if $\frac{\partial Div}{\partial w} < 0$, it can happen that the RHS of Equation (A.19) is greater than that of Equation (A.20). In that case $w^G < w^B$ since the LHS of the two equations is decreasing with $w$.

# B Additional calibration and simulation results

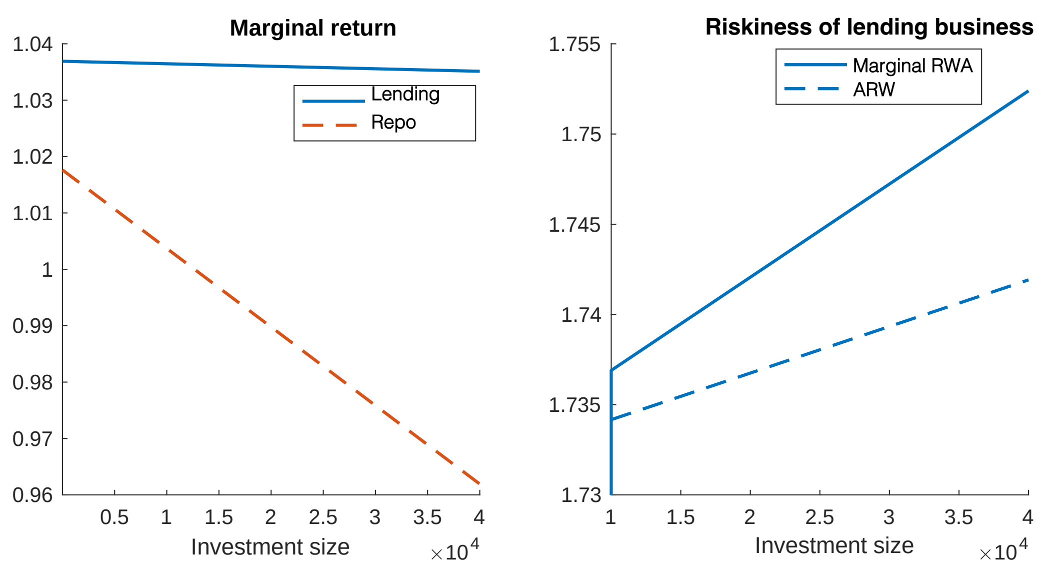
**Features of the calibrated business units.** In Figure B.1 we display the characteristics of the two business units of our calibrated bank. As seen in the left panel, the marginal

Table B.1: Data sources used for parameter calibration

| **Variable description** | **Timespan** | **Frequency** | **Data source** |
|---|---|---|---|
| Gross loans to customers | 2015-2018 | Semi-annual | S&P MI |
| Impaired loans | 2015-2018 | Semi-annual | S&P MI |
| Net interest margin | 2015-2018 | Semi-annual | S&P MI |
| Cost of funds | 2015-2018 | Semi-annual | S&P MI |
| Yield 15Y UK gilt | 2015-2018 | Daily | Factset |
| Repo Transaction Nominal Amount | 2017-2019 | Daily | SMMD |
| Repo interest rate | 2017-2019 | Daily | SMMD |
| Reverse repo Transaction Nominal Amount | 2017-2019 | Daily | SMMD |
| Reverse repo interest rate | 2017-2019 | Daily | SMMD |

returns on lending are higher compared to the repo returns. They also decrease at a much slower rate compared to the repo ones, as the investment size increases. In terms of riskiness, we observe from the right panel that the ARW of our calibrated lending business are globally higher than $\frac{\chi}{\gamma}$ which is equal to 0.35.

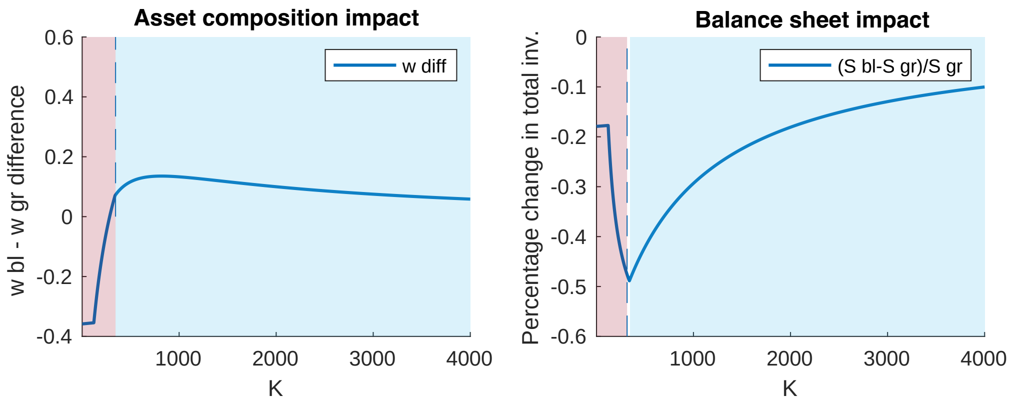
Figure B.1: Characteristics of the two business units




Note: This figure displays the main risk and return characteristics of the two business units of our calibrated bank. The left panel shows the marginal returns of repo and lending. The right panel shows two riskiness measures of the lending business, namely the marginal RWA and ARW.

**Optimal investments.**

Figure B.2: Bank's optimal investments




Note: This figure compares the bank's optimal investments in two cases:(i) when both regulatory constraints are applied at the group level and (ii) when the bank allocates both constraints down to its business units. The panels show the difference, between the two cases, in the bank's asset composition (left panel) and the bank's total investments (right panel). The dark pink area corresponds to the situation where both LR and RW constraints bind at the group level while in the light blue area, only RW constrain binds at the group level.

**Business model split and descriptives** We use a restricted set of ratios compared to Roengpitya et al. (2014) due to data availability, and we adjust downwards the threshold criteria to match our sample. Our criteria include the ratio of customer deposits to total liabilities for the stable source of funding ratio, the ratio of assets held for trading to total assets as a measure of tradable assets, loans to banks as the fraction of total assets for our inter-bank lending measure, and bank deposits to total liabilities as the bank deposit ratio. With these ratios in mind, we identify nine retail-funded, five wholesale-funded and one capital markets-oriented bank. Having one bank only in one group would not permit for a meaningful comparison, so we aggregate the wholesale with the capital markets-oriented bank, giving us a sample split into nine retail-funded, and six wholesale-funded and capital markets-orientated banks, to which we refer from now on as wholesale banks. Table B.2 reports some characteristics of each business model.

Further, in Figure B.3, we compare the two business models in terms of returns and riskiness of their lending business. As seen in the top left panel, the marginal returns of lending are higher for retail banks and decrease at a higher speed compared to wholesale banks. The two panels on the right show that the lending business of retail banks is riskier

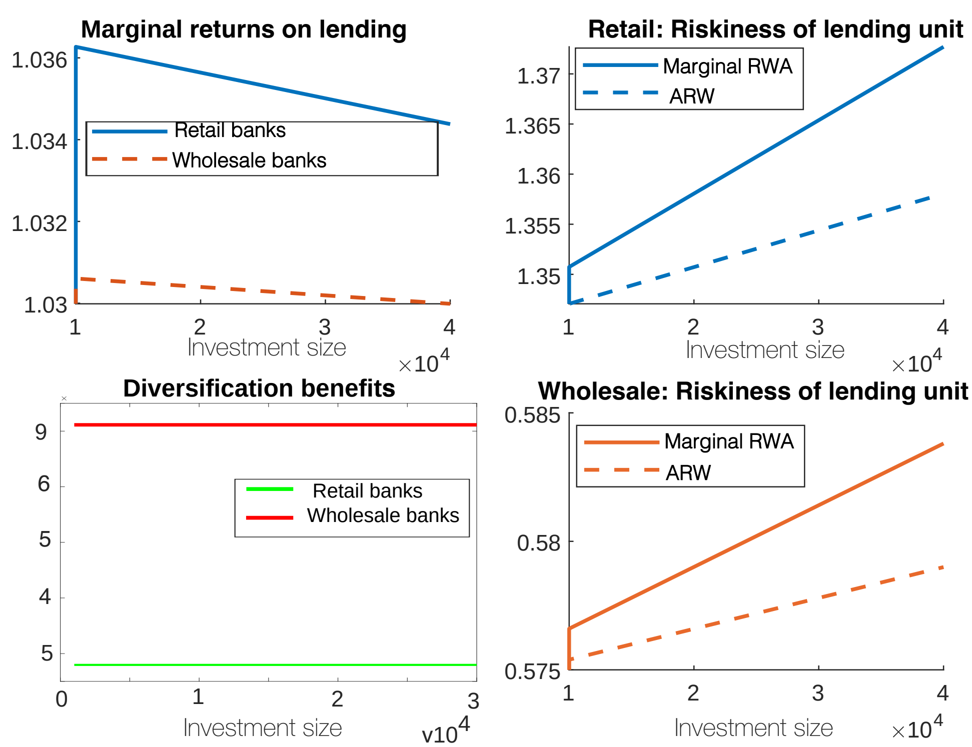
Table B.2: Business model descriptives

| Description | Values | |
|---|---|---|
| | **Retail** | **Wholesale** |
| Interest rate on unsecured debt | 0.0129<br>(47) | 0.009<br>(31) |
| Leverage ratio | 0.0549<br>(55) | 0.0529<br>(43) |
| Fully loaded risk-weighted capital ratio | 0.253<br>(43) | 0.185<br>(32) |
| Loans to total assets | 0.7649<br>(63) | 0.619<br>(43) |
| Percentage of impaired loans to total loan size | 1.11%<br>(53) | 2.04%<br>(28) |

The number of observations is in brackets, unless otherwise stated.

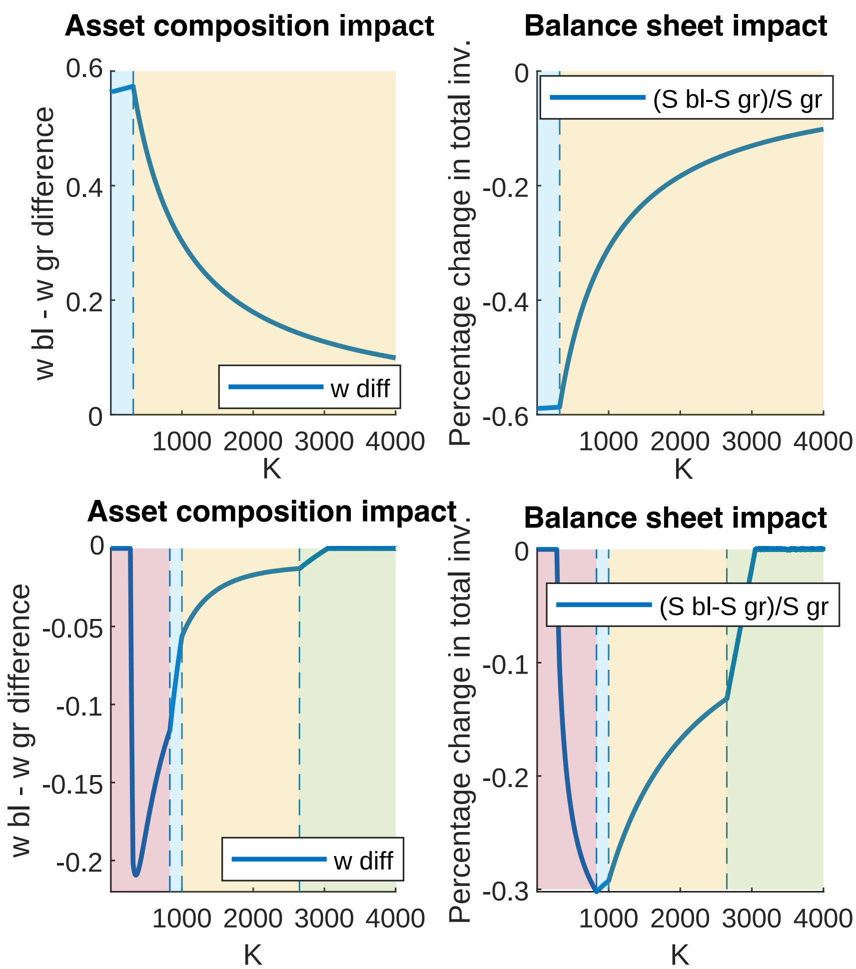
than that of wholesale banks.

Figure B.3: Characteristics of lending business across business models




Note: This figure compares some main characteristics of lending business across business models. The top left panel shows the marginal returns on lending. The bottom left panel shows, as a function of lending size, the diversification benefits defined as the difference between $RWA^L$ and $RWA^G$. In the two right panels, we represent the ARW and the marginal RWA as a function of investment in lending.

Figure B.4: Optimal investments: a comparison across business models




Note: This figure compares the optimal investments of retail banks (first row) and wholesale banks (second row) in two cases: (i) both regulatory constraints are applied at the group level and (ii) banks allocate both constraints to its business units. The panels represent the difference in, respectively, the share of the lending business and banks' total investments between the two cases. For all panels, the dark pink area corresponds to the situation where only the LR constraint binds at the group level; the light blue area to the case in which both LR and RW constraints bind; the beige area to the case where only RW constraint binds and finally the green area is when no constraints bind.