Bank of England

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Abstract

We argue that open banking will create diverse banking models: competitive banks (serving depositors who adopt open banking) and monopolistic banks (serving the other depositors). In equilibrium, at the margin, the profit of competitive and monopolistic banks should be equal. Hence, the system-wide impact of any policy change cannot be judged solely by the impact on a typical monopolistic or competitive bank, the impact on relative profitability also matters since this can lead banks to move from one banking type to another.

For example, an increase in capital requirements bites less on the profits of competitive than monopolistic banks. Some banks thus move to the (riskier) competitive sector which we show can increase overall risk in the system. A deposit rate ceiling dampens the impact of Bertrand competition, making competitive banks more profitable, so the (riskier) competitive sector grows. Hence, rather than making the system more stable, a marginal lowering of a deposit rate ceiling can increase risk. We also show that, in many scenarios, the regulator must choose between banks funding private sector projects or all banks being safe, the regulator cannot have both. This has implications for the optimal risk weights of sovereign debt. In our model, none of these effects are driven by the presence of unregulated assets/sectors nor on impacts on charter value, as is the case in papers that find outcomes that are the opposite of what was intended.

We then introduce an unregulated, shadow banking sector into the model and show that the growth in shadow banking benefits monopolistic banks relative to competitive banks. This increases the size of the (low-risk) monopolistic sector, reducing overall risk in the system. We discuss policy implications.

Key words: Capital requirements, banking, open banking, shadow banking, competition, FinTech.

JEL classification: D43, G21, G28.

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1 Introduction

In the last decade there have been significant innovations which allow third parties to obtain data on, and frequently access to, an individual's bank accounts and payments functionality. This allows the third parties to offer, through application programming interfaces (APIs), aggregate funds into the market and provide bespoke financial management advice and execution at low transaction cost. Such services go under a variety of names but are frequently referred to as open banking or open finance. Open Banking is expected to revolutionize financial intermediaries. In 2021 McKinsey's claimed that "if open finance continues to accelerate, it could reshape the global financial services ecosystem, change the very idea of banking, and increase pressure on incumbents".[1] Open banking is already present in the leading financial markets (e.g., US, EU, UK, China, Japan, Australia, Canada) and in nascent or more developed forms in 87% of countries around the world.[2]

Open banking increases diversity amongst depositors (who will be differentiated according to the extent that they embrace the new technology) and through this process will create a new competitive environment. Some banks and shadow banks will take full advantage of attracting deposits from those customers who embrace open banking and raise greater funds. The banks and shadow banks that follow this route will face strong competition from others who choose to follow a similar strategy. Depositors who do not embrace open banking are likely to retain limited opportunities, allowing some banks to adopt a strategy of focusing on these customers.[3] Banks which specialize in servicing depositors who do not take advantage of open banking may be able to make greater return per customer but will forgo the potential of attracting additional customers through open banking.

This paper shows that the introduction of Open Banking has significant implications for the market and regulation of banks. We first consider how open banking impacts the role traditional regulatory tools play in reducing risk taking by banks (i.e., capital requirements and deposit rate ceilings), and then consider how this is affected by the presence of unregulated competitors, i.e., shadow banks.

Capital requirements form a central component of modern banking regulation, based on the traditional view that the greater the capital requirement, then the more the banks have "skin-in-the-game" which, in turn, discourages their risk taking. However, whilst increasing capital requirements can reduce the incentives to take more risk, it can also negatively affect the charter value of banks which, in turn, can increase the incentive to take risk. Thus, the net effect of increasing capital requirements is unclear, as is shown by Hellman *et al.* (2000). Deposit rate ceilings are seen as an alternative mechanism to capital requirements to curb risk taking. This is because, higher deposit rates incentivize risk taking by banks, so imposing a ceiling on deposit rates should reduce risk taking, making the system safer.

[1] https://www.mckinsey.com/industries/financial-services/our-insights/financial-services-unchained-the-ongoing-rise-of-open-financial-data.

[2] https://www.finance-monthly.com/2019/11/open-banking-is-going-global-with-87-of-countries-having-open-apis/.

[3] Empirical evidence shows that traditional banking customers lose out relative to users of digital banking (e.g., Jiang *et al.* (2023), Koont *et al.* (2023)).

Shadow banks sit outside of the regulatory perimeter. The shadow banking sector has grown almost continuously over the last twenty years. Shadow banks' depositors do not have deposit protection (thus, receive higher deposit rates than depositors in traditional banks) and shadow banks do not have to meet capital requirements, thus they are seen as more risky than traditional banks. Tightening of regulation of traditional banks makes shadow banks more attractive and so raising capital requirements creates a leakage of funds into the higher risk shadow banking sector.[4] This reduces the efficacy of capital requirements (e.g., Plantin (2015)) and may even render them counterproductive (e.g., Martinez-Miera and Repullo (2019)).

In this paper, to look at the effects of regulatory policy in the presence of open banking, we model banks that are ex-ante identical. On the liability side some banks (which we label monopolistic) choose to set a low deposit rate, and consequently raise deposits only from depositors who do not take advantage of open banking (whom we label passive depositors). Other banks (which we label competitive) set a higher deposit rate in order to compete for the users of open banking (whom we label active depositors).[5] We show that the separation in terms of bank strategies on the liability side can lead to a separation of lending strategies on the asset side, with banks choosing between investing in low-risk and in high-risk assets. The prudential regulator is unable to distinguish between the two, thus has to set a common capital requirement. We also introduce a third asset category (referred to as government bonds) which is risk-free and can be observed by the regulator. Thus, it is not subject to capital requirements.

Our results provide a series of novel insights. First, an increase in the capital requirement can increase overall risk of the sector even though all banks are regulated, and there is no change in the risk of the investments of a typical monopolistic bank and no change in the risk of the investments of a typical competitive bank. Essentially, because of the pass-through effect (Repullo (2004)), banks competing for active depositors are unaffected by an increase in capital requirement since they can compensate for it by lowering the competitively set deposit rates. However, monopolistic banks cannot lower deposit rates because they are already offering the lowest possible deposit rate to captured (passive) depositors. Hence, an increase in capital requirement impacts monopolistic banks, reducing their profitability. To restore equilibrium some banks must leave the monopolistic sector and join the riskier competitive sector, raising overall risk of the banking sector.

Second, in many scenarios in our model, if the regulator sets capital requirements to ensure that competitive banks do not invest in risky (negative expected return) assets, then the only outcome

[4] A similar problem, albeit less dramatic, can arise with lending in foreign markets, e.g., Ongena *et al.* (2013) find higher restrictions on home-country bank activities, result in laxer lending standards in foreign markets.

[5] The fact that in equilibrium banks make the binary decision between exploiting only captured depositors or competing also for active ones arises because we assume (undifferentiated) Bertrand price competition for active depositors, with no price discrimination between passive and active depositors. This follows the approach that has been adopted to model the exploitation of behavioral biases affecting naive consumers, in contrast to sophisticated ones (e.g., Gabaix & Laibson (2006), Heidhues & Koszegi (2017)). The inability to price discriminate can also result from non-discriminatory requirements frequently imposed by conduct regulators with the aim of protecting passive consumers.

is that all banks invest solely in sovereign bonds. That is, the regulator cannot have both funding for the private sector and all banks being safe. This is because capital requirements are needed to prevent competitive banks investing in high-risk projects, on account of the pass-through effect, but as a result, low-risk projects are unattractive relative to government bonds (which, as an identifiable and risk-free investment, carry no capital requirement). Hence, although banks do not invest in high-risk projects, they also do not invest in any private sector projects.

Third, we show that a marginal lowering of a deposit rate ceiling increases rather than decreases risk of the sector. This is because deposit rate ceilings bite where deposit rates are highest, which is on the deposit rate of competitive banks. A ceiling dampens the negative aspects (from the bank perspective) of competing for deposits from active depositors, namely bidding up of deposit rates to zero marginal profitability. Lowering a deposit rate ceiling makes the competitive business model comparatively more attractive than the monopolistic one. Thus, introducing a deposit rate ceiling induces more banks to adopt the competitive (riskier) business model, and increases aggregate risk-taking as a result. It is worth pointing out that in our model, none of the effects identified so far are driven by the presence of unregulated assets/sectors nor on impacts on charter value, as is the case in other papers documenting outcomes that are the opposite of what was intended.

Finally, we consider the case where banks can opt to leave the regulatory perimeter and become shadow banks. We show that as the number of depositors able to access the shadow banks increases, then the proportion of all bank funds (i.e., regulated banks and shadow banks) invested in safe projects increases, and bank profits increase. The reason is that monopolistic banks (with lower deposit rates) benefit more than competitive banks from depositors who do not take up shadow banking. As a result, monopolistic banks are more profitable than competitive banks so, at the margin, some competitive banks must become monopolistic banks to restore parity.

Our research adds to the literature in several ways. One concerns the relationship between capital requirements and aggregate risk taking. The proposition that an increase in competition among banks for insured deposits can induce moral hazard in the form of risk shifting on the asset side of banks' balance sheets, and consequently that unregulated competition may be sub-optimal, has a long tradition and is well understood (e.g., Keeley (1990), Matutes & Vives (2000), Allen & Gale (2004), Freixes & Rochet (2008)). This leads to the question of whether the optimal response from a regulatory perspective should be to increase minimum capital requirements. Higher capital requirements tend to mitigate the limited liability effect identified by Jensen & Meckling (1976) in the static game (i.e., "skin-in-the-game" effect), but they also dilute the franchise value of banks in a dynamic fashion (i.e., gambling effect). Hellman *et al.* (2000) show that it is possible for the latter effect to offset the former, i.e., raising capital requirements may increase risk taking not reduce it. We also show that this can be true, but for different reasons than identified by Hellman *et al.* (2000). We show that the effect can be driven by diversity of business strategies adopted across banks. However, because our transmission channel is static in nature, it does not have to rely on the franchise value of banks. In addition to our mechanism being a theoretically separate effect, it also has different implications. As indicated, the effect in Hellman *et al.* (2000) relies on the change of capital requirements impacting the 'charter value'. Hence, a temporary change in current capital requirement would have no impact on "charter value", if the regulator could indeed credibly commit to the change being temporary. In contrast, since our transmission mechanism arises through a static framework, higher capital requirements could lead to greater risk in the system within the same period.

We also add to the literature on deposit rate ceilings. Deposit rate ceilings are an alternative regulatory approach to attempt to induce low-risk taking by banks, although they are also used to protect investors from monopoly power. They have a long history and are still a commonly used tool around the world (see Pinheiro & Esteves (2020) for a survey). Regulation Q in the US is probably the most well-known deposit rate ceiling, (see Sherman (2009) and Gilbert (1986)). Regulation Q included a deposit rate cap, which lasted in various forms for decades, and a deposit rate cap (the 'national rate cap') is still present in the US today. There is a large literature on the impact of deposit rate ceilings stretching back decades (e.g., Dann & James (1982), Smirlock (1984)). More recent literature seems to indicate and emphasise the effects of deposit rate ceilings on the quantity of loans and particularly the flow of funds away from bank deposits to unregulated uninsured alternatives (e.g., Lucas (2013), Koch (2015), Ben-David *et al.* (2017), Egan (2017), Nielsen & Weinrich (2019), Cubillos-Rocha *et al.* (2021)). Looking at the regulated single bank level, introducing a deposit rate may reduce risk taking, hence models using representative banks could indicate lower risk (e.g., Hellman *et al.* (2000)) if there are no unregulated uninsured alternatives. However, where there is diversity of banks, a deposit rate ceiling impacts those banks with the highest deposit rates, and these will frequently be the most competitive banks (in our model these are banks competing for depositors that use open banking). We show that the introduction of a ceiling ameliorates the competitive pressures on these banks, increasing their profitability, and at the margin makes joining the competitive sector more attractive than remaining in the monopolistic sector. Since the competitive sector is riskier than the monopolistic sector, aggregate risk increases even though the deposit rate ceiling has not increased the risk of the typical monopolistic or competitive bank, and there are no unregulated uninsured alternatives available.

There has been considerable discussion about the favouring of sovereign debt through its treatment in banking regulation (see Willems & Zettelmeyer (2022) for a survey). This has frequently been seen as problem in the EU where banks may be holding disproportionate amounts of sovereign debt for capital and liquidity reasons (Craig *et al.* (2020)). We add to this literature by showing that the imposition of high capital requirements needed to prevent competitive banks choosing to invest in risky assets may result in banks completely sidestepping investing in private sector low-risk projects to invest in sovereign debt instead. As a result, even when sovereign debt is zero risk, it may not be optimal to set a zero risk weight.

Finally, there is a substantial literature on shadow banking. Shadow banking, being outside of the regulatory perimeter, creates problems for regulators (e.g., Boot & Thakor (2019), Duffie (2018), Liu and Xie (2021), Tian (2022)) and raises corporate governance issues (Awray & Macey (2022)). Tighter banking regulation increases the flow of funds to shadow banks which reduces the efficacy of regulation and may suggest loosening of regulation (Plantin (2015)). If the leakages of regulated funds to the shadow banking sector are sufficient, then tightening regulation can have the opposite effect to that intended and increase risk in the financial system (Abad *et al.* (2017), Huang (2018), Martinez-Miera & Repullo (2019), Neilsen & Weinrich (2023)). However, Begenau & Landvoigt (2017) argue that although tighter regulation increases the size of the shadow banking sector, it also eliminates the subsidies to commercial banks from deposit insurance, reducing the competitive pressures on shadow banks to take risks. The net effect can lead to lower overall risk in the system. We contribute to this literature by showing that when accessing shadow banking becomes easier for depositors (and hence shadow banking grows), the overall risk in the system can fall because monopolistic banks benefit more from the growth of shadow banking than competitive banks and, as a result, at the margin, some (riskier) competitive banks choose to become (less risky) monopolistic banks.

The paper is structured as follows. The next section sets out the structure and assumptions of the model. Section 3 contains the formal analysis, and implications for overall risk, capital requirements and the capital structures of banks. Section 4 presents an extension to shadow banking ceiling. Finally, Section 5 discusses policy implications of the model and concludes.

2 Model

As indicated in the introduction the central feature of our model is that there are two types of depositors: (i) passive depositors, who, subject to receiving a specific minimum rate, stay with the bank they are attached to; and (ii) active depositors who take advantage of open banking to search all the rates offered by other banks and choose the highest offer. This partition motivates two opposing strategies on the supply side, with: (i) monopolistic banks, intent on exploiting their passive depositors, rather than competing for active ones; as opposed to (ii) competitive banks, offering higher deposit rates to attract active depositors, thus benefiting also their passive ones (i.e., banks cannot price discriminate between the two categories of depositors). In equilibrium, the split among banks is determined endogenously so that at the margin a monopolistic bank cannot gain by becoming competitive and vice versa.

2.1 Actors

There are three types of actors: banks, depositors and capital investors. There is a continuum of banks indexed $j \in [0, 1]$. Each bank j is owned by N_0 existing shareholders and each shareholder owns a single share. Initially each bank has no funds, and in the first stage each bank simultaneously raises funds from depositors and capital investors. In particular, in the first stage shareholders of each bank simultaneously choose (i) a number of new shares N_j to offer to outside capital investors, (ii) a share price τ_j and (ii) a deposit rate s_j. In the second stage each bank invests funds collected from capital investors and depositors into three types of projects: a high-risk project (H), a low-risk project (L) and government bonds (B). Choices in both stages are made to maximize expected shareholder return. This is discussed in detail later.

There is a continuum of small depositors indexed $i \in [0, D]$ who each hold a unit of funds they may choose to deposit with one of the banks. Let $\mu \in [0, 1]$ be equal to the proportion of funds held by active depositors and, as such, can be thought of as a measure of Open Banking intensity. Let $d_m = (1 - \mu)D$ be equal to the total funds held by passive depositors. Both active and passive depositors also have the choice to invest in an outside option and obtain a return s_0.[6]

There also is a large pool of capital investors who provide capital to banks by purchasing their shares. The opportunity cost of capital for capital investors is c_0 for every unit of capital supplied (i.e. they could obtain c_0 elsewhere from each unit of funds invested in an alternative safe investment). We assume that $c_0 > s_0$, hence the outside option c_0 of capital investors in alternative capital markets is greater than the outside option s_0 of depositors in the deposit market.

2.2 Fund raising stage

Let s^c denotes the competitive deposit rate i.e., the highest deposit rate set by any bank. We assume that banks cannot segment the deposit market and must offer the same deposit rate to active and passive depositors. Each active depositor chooses to deposit funds at one of those banks offering the competitive deposit rate s^c. Passive depositors attached to bank j either (i) deposit their funds with bank j if $s_j \geq s_0$ or (ii) take their outside option if $s_j < s_0$. Let d_j be the total quantity of deposits raised by bank j from passive and active depositors. Finally, we assume that banks are ex-ante identical i.e., (i) each bank offering a deposit rate $s_j \geq s_0$ receives the same amount of deposits from passive depositors and (ii) each bank offering the competitive deposit rate s^c receives the same amount of deposits from active depositors.

In order to attract new shareholders, each bank j issues an additional N_j shares and sells these shares to capital investors at a price τ_j per share. Each bank j sets its share price τ_j to ensure investing in bank capital is at least as attractive as the outside option c_0 available to new shareholders. Once bank j has collected funds from new shareholders, these funds are used as bank capital (k_j). Hence $k_j = N_j \tau_j$.[7]

2.3 Investment stage

In the second stage, each bank j simultaneously chooses to invest $\theta_j^X \geq 0$ where $X \in \{L, H, B\}$. Let $\theta_j = (\theta_j^L, \theta_j^H, \theta_j^B)$ capture the investment allocation of bank j. Each bank must take into account two

[6] Anyone opting for the outside option may need to make alternative arrangements to meet their requirements for payment services and suchlike. In the absence of depositing with a bank, this may be costly, so we think of s_0 as net of the cost of accessing such services.

[7] Note, that since all banks are ex-ante identical the shares of all banks are equally valuable in the fund raising stage. In particular, $\tau_j = \tau^*$ for all j.

constraints when choosing how much to invest in each project: (i) $k_j + d_j = \theta_j^L + \theta_j^H + \theta_j^B$; (ii) each bank j must comply with the capital ratio q set by the regulator i.e.,

$$\frac{\theta_j^L + \theta_j^H}{k_j} \geq q.$$

Bank revenues vary depending on whether low-risk and high-risk projects are successful. If bank j invests in high-risk projects, its return from these investments are $R_H(\theta_j^H)$ if high-risk projects are successful, and 0 if high-risk projects fail. Similarly, if bank j invests in low-risk projects, its return from these investments are $R_L(\theta_j^L)$ if low-risk projects are successful, and 0 if they fail. Given that government bonds are a safe investment, bank j always earns a return of $R_B(\theta_j^B)$ on its investment in government bonds. It follows that total revenue of bank j equals $R_j = R_j(\theta_j)$ where:

$$R_j(\theta_j) = \begin{cases} R_L(\theta_j^L) + R_H(\theta_j^H) + R_B(\theta_j^B) & \text{if both low- and high-risk projects are successful} \\ R_L(\theta_j^L) + R_B(\theta_j^B) & \text{if only low-risk projects are successful} \\ R_H(\theta_j^H) + R_B(\theta_j^B) & \text{if only high-risk projects are successful} \\ R_B(\theta_j^B) & \text{if both low- and high-risk project are unsuccessful} \end{cases}$$

For $X \in \{L, H, B\}$ we assume that (i) $R_X(0) = 0$ and (ii) $\delta R_X(\theta_j)/\delta\theta_j = \underline{r}_X + (\overline{r}_X - \underline{r}_X)/(1+\theta_j)$ where $\overline{r}_X - \underline{r}_X = \Delta_X > 0$. The first condition captures the fact that if bank j does not invest in project X (i.e. $\theta_j^X = 0$), then the bank earns no revenue from this project. The second condition captures the fact that the marginal return of project X lies in the interval $[\underline{r}_X, \overline{r}_X]$, and that this marginal return decreases as the amount bank j invests in project X increases. Low-risk projects succeed with probability $p_L \leq 1$, while high-risk projects succeeds with probability $p_H < p_L$.

We assume that high-risk projects fail whenever low-risk projects fail, which captures the fact that the success of both types of projects depend on common macroeconomic conditions. In addition we assume that both Δ_B and Δ_L are sufficiently small which captures a setting where the marginal return on investment in the risky projects and government bonds decreases slowly as the amount invested increases.[8]

We also assume that (i) $\overline{r}_L < \underline{r}_H$, so that high-risk projects have greater upside potential than low-risk projects and (ii) $\overline{r}_B < \underline{r}_L$ so that low-risk projects have greater upside potential than government bonds. Finally, we assume (i) $p_H\overline{r}_H < \underline{r}_B$, so that high-risk projects have lower expected return than government bonds, (ii) $\overline{r}_B < p_L\underline{r}_L$, so that low-risk projects have higher expected return than government bonds and (iii) $p_L\overline{r}_L < c_0$ so that low-risk projects have lower expected returns than the outside option available to capital investors. This set of assumptions captures a situation where a social planner aiming to maximize total (expected) project return would aim to maximize investment in low-risk projects while minimizing investment in high-risk projects.

[8] In particular, we assume $\Delta_B = \Delta_L < \min\{p_H\Delta_H, p_L\overline{r}_L - p_H\underline{r}_H\}$.

In the case where the overall revenue bank j receives from its project portfolio is lower than the amount bank j is obliged to pay to depositors (i.e $R_j < d_j s_j$), bank j becomes insolvent. We assume that depositors are fully insured by the regulator (i.e. when bank j becomes insolvent, in order to ensure depositors are fully compensated, the regulator incurs a cost $d_j s_j - R_j > 0$).

2.4 Shareholder return

After collecting revenue from projects, the bank first pays depositors. Any residual funds are distributed evenly among all shareholders. Each shareholder receives the following payment:

$$\pi_j = \frac{\max\{R_j - d_j s_j, 0\}}{N_0 + N_j}.$$

Recall that each bank j chooses: (i) a number of new shares to issue N_j; (ii) an issuance price τ_j; (iii) a deposit rate s_j; and (iv) an investment allocation θ_j to maximize expected shareholder return. Each bank j must also ensure it complies with the capital ratio set by the regulator, and that new shares are a sufficiently attractive investment for capital investors (i.e., compared to their outside option). This motivates the following definition of equilibrium:

Definition 1 *We say the vector $\{N_j, \tau_j, s_j \theta_j\}_{j\in[0,1]}$ is an equilibrium if for any given bank j:*

1. *The bank complies with the capital ratio:*

$$(\theta_j^L + \theta_j^H)/k_j \geq q$$

2. *Capital investors are willing to invest in new shares:*

$$E[\pi_j] \geq c_0 \tau_j$$

3. *Given any deviation $\{\hat{N}_j, \hat{\tau}_j, \hat{s}_j \hat{\theta}_j\}$ one of the following is true:*

   - *Expected shareholder return of bank j before deviating is greater (or equal) to the profit of bank j after deviating (i.e., $E[\pi_j] \geq E[\hat{\pi}_j]$)*
   - *After deviating, capital investors prefer to choose their outside option rather than investing in new shares of bank j (i.e., $c_0 > E[\hat{\pi}_j]/\hat{\tau}_j$)*
   - *After deviating, bank j does not comply with the capital ratio (i.e., $(\hat{\theta}_j^L + \hat{\theta}_j^H)/\hat{N}_j \hat{\tau}_j < q$).*

3 Analysis

Until specified otherwise, for simplicity, we restrict attention to the case where $p_L = 1$ so that the low-risk projects always succeed. Note that it is straightforward to show that the results presented for this case (i.e., $p_L = 1$) continue to hold when p_L is less than but sufficiently close to 1. We define two critical levels of capital requirement: (i) $\underline{q}_{LB}$ such that $\underline{r}_L - \underline{q}_{LB}(c_0 - \underline{r}_L) = \overline{r}_B$ and (ii) $\overline{q}_{LB}$ such that $\overline{r}_L - \overline{q}_{LB}(c_0 - \overline{r}_L) = \underline{r}_B$. The following holds:

Lemma 3.1 *Regardless of the deposit rate offered by banks:*

1. *If the capital ratio is sufficiently low (i.e., $q < \underline{q}_{LB}$), then banks do not invest in government bonds*

2. *If the capital ratio is sufficiently high (i.e., $q > \overline{q}_{LB}$), then banks do not invest in the low-risk projects.*

Note that when the capital ratio is low, low-risk projects are a more attractive investment (compared to government bonds) since low-risk projects have higher returns. On the other hand, when the capital ratio is high, government bonds become a more attractive investment because banks do not need to hold costly capital against this asset. Finally when the capital ratio lies between these two thresholds (i.e., $q \in (\underline{q}_{LB}, \overline{q}_{LB})$), banks may invest in both low-risks project and government bonds simultaneously. The following proposition brings together a number of preliminary results:

Proposition 3.2 *There exists a unique equilibrium market structure where*

1. *Every bank j holds the minimum amount of capital with $\theta_j^L + \theta_j^H = qk_j$*

2. *A proportion $(1 - \gamma_c)$ of banks choose to be monopolistic banks, set a deposit rate s_0 and raise deposits d_m*

3. *A proportion γ_c of banks choose to be competitive banks, set a deposit rate $s_c > s_0$ and raise deposits $d_c > d_m$*

4. *All active depositors are served and hence $\mu D = \gamma_c(d_c - d_m)$*

The intuition behind this proposition is as follows. First, banks choose to hold the minimum amount of capital because capital is costly and, in particular, the expected return banks can achieve by investing in projects is always lower than the return accessible to capital investors elsewhere (since $c_0 > \overline{r}_L$). Second banks choose either to be monopolistic focusing only on their passive depositors by setting a low deposit rate s_0, or choose to be competitive focusing on both active depositors and their passive depositors by setting a deposit rate $s^c > s_0$.[9] No bank selects an intermediate deposit rate (i.e. $s_0 < s_j < s^c$), since charging an intermediate deposit rate would not attract more price-sensitive active depositors but would increase payments made to price-insensitive passive depositors. Third the quantity of active depositors served by each competitive bank - namely $(d_c - d_m)$ - is determined by the extent of Open Banking μ and the proportion of competitive banks in the market γ_c. This shows that as more banks enter the competitive sector the quantity of active depositors served by each competitive bank decreases (i.e., $(d_c - d_m)$ decreases as γ_c increases).

[9]The view that differences in monopolistic power impacts deposit rates is supported in the empirical literature (e.g., Degryse *et al.* (2019)).

Although Proposition 3.2 partially characterizes the equilibrium market structure, it leaves some unanswered questions concerning whether or not banks invest in low-risk projects, high-risk projects or government bonds (or some combination). In the following three subsections, we provide a more complete discussion of market outcomes under three different scenarios. First, we investigate the scenario where there is no Open Banking (i.e., $\mu = 0$), so that all banks are monopolistic. Second, we investigate the scenario where there is full adoption of Open Banking (i.e., $\mu = 1$), so that all banks have to be competitive banks and compete for active depositors. Third, we investigate the scenario where there is partial adoption of Open Banking (i.e., $0 < \mu < 1$) in which case monopolistic banks and competitive banks can coexist in the market. In each scenario we discuss banks' investment decisions and the impact of increasing the capital ratio on aggregate risk taking.

3.1 No Open Banking

If Open Banking has not been adopted and there are no active depositors (i.e., $\mu = 0$), there is no incentive for banks to set a high deposit rate and, in particular, every bank j will choose to be monopolistic setting a deposit rate equal to the outside option of depositors (i.e. $s_j = s_0$). When the capital ratio is sufficiently low banks are willing to risk insolvency for the chance of earning high returns and thus prefer to invest in high-risk projects rather than low-risk projects. When the capital ratio is sufficiently high then banks start to act more cautiously and avoid investing in high-risk projects. From now on we say that a bank chooses to adopt a risky (safe) business model if it chooses (not) to invest funds in high-risk projects. We define the critical threshold q^m_{HL} to be the capital ratio that ensures monopolistic banks (who hold a quantity of deposits d_m and pay a deposit rate s_0) are indifferent between choosing a risky business model and a safe business model.[10] Using this critical threshold, the following result holds:

Proposition 3.3 *Suppose no depositors adopt Open Banking (i.e., $\mu = 0$). If the cost of deposits is sufficiently low (i.e., $s_0 < s_0^*$), then $q^m_{HL} < \underline{q}_{LB}$. Furthermore:*

1. *If the capital ratio is low (i.e. $q < q^m_{HL} < \underline{q}_{LB}$), then banks invest only in high-risk projects*

2. *If the capital ratio is intermediate (i.e., $q^m_{HL} \leq q < \underline{q}_{LB}$), then banks invest only in low-risk projects*

3. *If the capital ratio is high (i.e., $q \geq \overline{q}_{LB}$), then banks invest only in government bonds.*

This result shows that if the outside option of depositors is sufficiently low (i.e., $s_0 < s_0^*$), as the capital ratio increases, banks abandon the risky business model and invest in low-risk projects.[11] As

[10]Note, that q^m_{HL} satisfies the following equation:

$$p_H \max_{\theta^B} \left\{ R_H\Big(d_m/(1 - q^m_{HL}) - \theta^B\Big) + R_B(\theta^B) - d_m s_0 \right\} = \max_{\theta^B} \left\{ R_L\Big(d_m/(1 - q^m_{HL}) - \theta^B\Big) + R_B(\theta^B) - d_m s_0 \right\}$$

.

[11]We define $\overline{q}^m_{HL}$ so that:

$$\underline{r}_L - (1 - \overline{q}^m_{HL})s_0 = p\Big(\overline{r}_H - (1 - \overline{q}^m_{HL})s_0\Big)$$

the capital ratio increases further, though, banks are no longer willing to invest in low-risk projects and instead invest in government bonds in order to eschew excessive capital requirements. Since all depositors are passive in this scenario, banks choose to pay a deposit rate equal to the outside option of depositors (i.e. $s_j = s_0$). On the other hand, if the deposit rate is higher (i.e. $s_0^{**} < s_0 < \underline{r}_H$ and $c_0 > c_0^{**}$), then high-risk projects become relatively more attractive compared to low-risk projects. In this case, $\overline{q}_{LB} < q_{LH}^m$ and there is an intermediate critical threshold $q_{HB}^m \in (\overline{q}_{LB}, q_{LH}^m)$ such that when $q = q_{HB}^m$ banks are indifferent between investing solely in high-risk projects and solely government bonds. In this case (i) banks invest solely in high-risk projects if the capital ratio is low (i.e., $q < q_{HB}^m < q_{LH}^m$), (ii) banks invest only in government bonds if the capital ratio is high (i.e., $q > q_{HB}^m > \overline{q}_{LB}$) and (iii) banks never invest in low-risk projects regardless of the capital ratio. This shows that if the deposit rate paid to depositors is sufficiently high, then it is not possible for the regulator to design regulation in order to ensure banks invest in low-risk projects.[12] Note, that the following corollary holds regardless of the exact level of s_0:

Corollary 3.4 *Suppose no depositors adopt Open Banking (i.e., $\mu = 0$), then a small increase in the capital ratio will not increase the overall proportion of funds invested in high-risk projects.*

This corollary follows from the fact that as the capital ratio increases, fewer banks invest in high-risk projects and more banks choose to invest in either low-risk projects or government bonds (or some combination of these two). Hence, when there is no Open Banking the imposition of capital requirements is effective at reducing risk-taking in the banking sector.

3.2 Full adoption of Open Banking

Now let us assume that there is full adoption of Open Banking, i.e., all depositors are active ($\mu = 1$). We define the threshold of the capital requirement $\underline{q}_{HB}^c$ to satisfy the following equation:

$$(1 - \underline{q}_{HB}^c)(p_H \underline{r}_H - p_H \overline{r}_B) - \underline{q}_{HB}^c (c_0 - p_H \underline{r}_H) = 0.$$

Note, that the first term captures the minimum return that could be earned on deposits (per unit of asset) by a bank which sets a deposit rate $s_j = \overline{r}_B$ and then invests in risky projects. The second term captures the maximum loss that could be made on capital (per unit of asset) by a bank which sets a deposit rate $s_j = \overline{r}_B$ and then invests in risky projects. It follows that when $q < \underline{q}_{HB}^c$, a competitive bank investing solely in risky projects will always be able to pay a deposit rate $s_j > \overline{r}_B$.

Using this, we define the critical threshold s_0^* so that if $s_0 = s_0^*$, then $\overline{q}_{LH}^m = \underline{q}_{LB}$. We show in the Appendix that $q_{HL}^m < \overline{q}_{HL}^m$. Note, that as s_0 increases (i) both q_{HL}^m and $\overline{q}_{HL}^m$ decrease, and (ii) $\underline{q}_{LB}$ remains constant. Hence, when $s_0 \leq s_0^*$, then $q_{HL}^m < \overline{q}_{HL}^m \leq \underline{q}_{LB}$.

[12] We define the thresholds s_0^{**} and c_0^{**} in the Appendix. We then prove that banks setting a deposit rate $s_j = s_0$ never invest in low-risk projects regardless of the capital ratio whenever $s_0^{**} < s_0 < \underline{r}_H$ and $c_0 > c_0^{**}$.

In contrast, a competitive bank investing solely in government bonds cannot afford to pay a deposit rate $s_j > \overline{r}_B$. This motivates the following result:[13]

Proposition 3.5 *Suppose all depositors adopt Open Banking (i.e., $\mu = 1$). If the return on government bonds is sufficiently close to the return on low-risk projects (i.e. $r_B^* < \overline{r}_B < \underline{r}_L$), then:*

1. *If the capital ratio is sufficiently low (i.e. $q < \underline{q}_{HB}^c$), then banks invest only in high-risk projects*
2. *If the capital ratio is sufficiently high (i.e. $q > \underline{q}_{HB}^c$), then banks invest in high-risk projects and/or government bonds*

This result shows that if the return on government bonds is sufficiently high (i.e., $\overline{r}_B > r_B^*$), then (i) when the capital ratio is sufficiently low banks invest only in the high-risk projects and (ii) banks never invest in low-risk projects. If $\overline{q}_{LB} < q < \underline{q}_{HB}^c$, government bonds are a more attractive investment than low-risk projects (since $q > \overline{q}_{LB}$) but a less attractive investment than high-risk projects (since $q < \underline{q}_{HB}^c$). Therefore, the high-risk projects are the most attractive investment when $\overline{q}_{LB} < q < \underline{q}_{HB}^c$, and since a lower capital ratio makes high-risk projects relatively more attractive compared to the other projects it must follow that the high-risk projects are also the most attractive investment whenever $q < \underline{q}_{HB}^c$. Note, that if the return on government bonds is low (i.e., $\overline{r}_B < r_B^*$), this makes low-risk projects relatively more attractive compared to government bonds. In this case the regulator may be able to choose an intermediate capital ratio to ensure that competitive banks invest in low-risk projects. The following corollary holds regardless of the exact level of return on government bonds:

Corollary 3.6 *Suppose all depositors adopt Open Banking (i.e., $\mu = 1$), then a small increase in the capital ratio will not increase the overall proportion of funds invested in high-risk projects.*

This corollary follows from the fact that as the capital ratio increases, fewer banks invest in high-risk projects and more banks choose to invest in government bonds (or possibly low-risk projects, if $\overline{r}_B < r_B^*$). Hence, when all depositors embrace Open Banking the imposition of capital requirements is effective at reducing risk taking in the banking sector. Now, recall that any bank j that chooses to set a deposit rate $s_j < s_c$ only serves passive depositors and, hence, holds a quantity of deposits $d_j = (1-\mu)D$. It follows that if Open Banking has been adopted by most depositors (i.e., μ is close to 1), a bank serving only passive depositors will have only a very small deposit base. Such a small deposit base will in turn translate into a low return for shareholders. This suggests that if μ is sufficiently close to 1, then no banks will set a deposit rate $s_j < s^c$. Finally, we define μ_+^* such that whenever $\mu > \mu_+^*$, all banks set a deposit rate $s_j = s^c$, and define μ^* such that whenever $\mu < \mu^*$ at least some banks set a deposit rate $s_j < s^c$ (note that $0 < \mu^* \leq \mu_+^* < 1$).[14] This allows us to state

[13] Note, the critical threshold $r_B^* < \underline{r}_L$ satisfies following equation (this is discussed further in the Appendix):

$$\frac{p\underline{r}_H - pr_B^*}{c_0 - pr_B^*} = \frac{\overline{r}_L - \Delta_B - r_B^*}{c_0 - \overline{r}_L}$$

.

[14] The critical thresholds μ^* and μ_+^* are defined in the Appendix.

the following result:

Corollary 3.7 *Suppose that Open Banking has been adopted by most - but not all - depositors (i.e.,* $\mu_+^* \leq \mu < 1$*), then every bank* j *chooses the competitive deposit rate* $s_j = s^c$*. Furthermore, increased adoption of Open Banking by depositors (increasing* μ*) will not change the competitive deposit rate, the amount of capital raised or investment decisions.*

It follows that as μ increases from $\mu = \mu_+^* < 1$ towards 1 outcomes do not change.

3.3 Partial adoption of Open Banking

Now let us consider the scenario where there is partial adoption of Open Banking with some active depositors and some passive depositors (ie $0 < \mu < \mu^*$). The proposition below brings together the previous results and states which projects monopolistic banks and competitive banks choose to invest in as the capital ratio changes:

Proposition 3.8 *Suppose only some depositors adopt Open Banking (i.e.* $0 < \mu < \mu^*$*) and that (i) the cost of deposits is low (i.e.* $s_0 < s_0^*$*) and (ii) the return on government bonds is close to the return on the low-risk projects (i.e.* $r_B^* < \overline{r}_B < \underline{r}_L$*). Then:*

1. *If the capital ratio is low (i.e.* $q < q_{HL}^m$*), then all banks invest solely in high-risk projects*
2. *If the capital ratio is intermediate (i.e.* $q_{HL}^m < q < \underline{q}_{HB}^c$*), then competitive banks invest solely in high-risk projects while monopolistic banks invest in the low-risk projects (and/or government bonds)*
3. *If the capital ratio is high (i.e.* $q > \underline{q}_{HB}^c$*), then competitive banks invest high-risk projects (and/or government bonds) while monopolistic banks invest solely in government bonds.*

Note that competitive banks have a greater tendency (in comparison to monopolistic banks) to invest in risky projects. In particular, when the capital ratio is intermediate (i.e., $\overline{q}_{HL}^m < q < \underline{q}_{HB}^c$), monopolistic banks choose a safe business model while competitive banks choose a risky business model. This follows from the fact that monopolistic banks charge a lower deposit rate and have weaker incentives to take excessive risks. From Proposition 3.8, we can deduce the following corollary:

Corollary 3.9 *Suppose the conditions in Proposition 3.8 hold (i.e.* $\mu \in (0, \mu^*)$*,* $s_0 < s_0^*$*, and* $\overline{r}_B \in (r_B^*, \underline{r}_L)$*). Then, either (i) competitive banks invest only in high-risk projects or (ii) all banks invest only in government bonds.*

Corollary 3.9 shows that under certain conditions the regulator can choose between: (i) a higher capital requirement which ensures both monopolistic banks and competitive banks invest in government bonds, or (ii) a lower capital requirement which incentivizes monopolistic banks to invest in low-risk projects and competitive banks to invest in high-risk projects. Under such conditions, the regulator cannot prevent investment in high-risk projects without choking off investment in low-risk projects, so must choose between allowing risky competitive banks to operate in the market or eliminating investment in all private projects (i.e., low-risk projects and high-risk projects). Finally, when there is a small increase in the capital ratio the following holds:

Proposition 3.10 *Suppose that only some depositors adopt Open Banking (i.e., $0 < \mu < 1$) and that (i) the cost of deposits is low (i.e. $s_0 < s_0^*$), (ii) the return on government bonds is close to the return on the low-risk projects (i.e. $r_B^* < \overline{r}_B < \underline{r}_L$) and (iii) the capital ratio is intermediate (i.e. $q_{HL}^m \leq q < \underline{q}_{HB}^c$). Then, a small increase in the capital ratio causes the proportion of funds invested in high-risk projects to increase.*

Recall that when no depositors adopt Open Banking (i.e., $\mu = 0$) and also when all depositors adopt Open Banking (i.e., $\mu = 1$, all banks are competitive), increasing the capital ratio does not cause the proportion of funds invested in risky projects to increase. However, in the intermediate case, when some depositors adopt Open Banking (i.e., $0 < \mu < \mu^*$), an increase in the capital ratio can create incentives for banks to switch away from being monopolistic (with a safe business model) to being competitive (with a risky business model). An increase in the capital ratio makes the competitive sector relatively more attractive, since competitive banks can pass on the additional costs associated with higher capital requirements by lowering the deposit rate offered to depositors (i.e., s^c drops as q increases). Monopolistic banks - who are already charging the minimum deposit rate s_0 - have no room to pass on the additional costs by lowering deposit rates. Therefore some monopolistic banks switch to the competitive sector, thus increasing aggregate risk taking.

3.4 Deposit rate ceilings

We now consider an extension of the model in order to investigate the impact of deposit rate ceilings, with a particular focus on the case where the capital ratio is at an intermediate level and there is partial adoption of Open Banking so that both types of business model (monopolistic and competitive banks) are present. The regulator sets a deposit rate ceiling s_R, so that each bank j must choose a deposit rate $s_j \leq s_R$. If the regulator chooses a deposit rate ceiling above the unconstrained competitive deposit rate discussed above (i.e., $s_R > s^c$), then competitive banks continue to pay depositors a deposit rate of s^c. In this case, the introduction of a deposit rate ceiling does not influence banks' decision making or market outcomes. On the other hand, if the regulator chooses a deposit rate ceiling below the unconstrained competitive deposit rate (with $s_R < s^c$), then the deposit rate paid by competitive banks falls from s^c to s_R. This drop in the competitive deposit rate will cause the profitability of competitive banks to increase (relative to monopolistic banks) and this will induce some banks to switch from the monopolistic business model to the competitive business model. The following result considers the case where the deposit rate ceiling is below - but relatively close - to s_R:

Proposition 3.11 *Suppose only some depositors adopt Open Banking (i.e., $0 < \mu < \mu^*$) and that (i) the cost of deposits is low (i.e., $s_0 < s_0^*$), (ii) the return on government bonds is close to the return on the low-risk projects (i.e., $r_B^* < \overline{r}_B < \underline{r}_L$), (iii) the capital ratio is intermediate (i.e., $\overline{q}_{HL}^m \leq q < \overline{q}_{LB}$) and (iv) the unconstrained competitive deposit rate without a deposit rate ceiling equals s^c. Then,*

1. *If the deposit rate ceiling is above the unconstrained competitive deposit rate (i.e., $\overline{s} > s_c$), then a small decrease in the deposit rate ceiling has no effect*

2. *If the deposit rate ceiling is equal to the unconstrained competitive deposit rate (i.e., $\overline{s} = s_c$), then a small decrease in the deposit rate ceiling causes the proportion of funds invested in the risky project, to increase.*

Recall that when the capital ratio is at an intermediate level, monopolistic banks choose to invest in low-risk projects while competitive banks choose to invest high-risk projects. In this scenario, lowering the deposit rate ceiling increases aggregate risk taking by encouraging monopolistic banks to adopt a more competitive business model and re-balancing their portfolios towards the risky projects. While Hellman *et al.* (2000) showed that the imposition of deposit rate ceilings decreases aggregate risk taking in a setting where all banks offer the same deposit rate, the impact of deposit rate ceilings is less clear-cut in a banking sector where banks may pursue different strategies and may offer different deposit rates. On the one hand, deposit rate ceilings may force some banks to lower their deposit rates to the deposit rate ceiling and reduce incentives to take excessive risks. On the other hand, the resulting comparative improvement in profitability may encourage more banks to adopt a competitive business model and raise their deposit rates to the deposit rate ceiling in order to compete for active depositors thereby increasing incentives to take excessive risks. Proposition 3.11 provides conditions under which the second effect dominates the first effect and, in particular, it provides conditions for when the introduction of a deposit rate ceiling increases risk taking in aggregate.

4 Shadow banking

We now consider a situation where before raising capital and deposits each bank decides to operate inside the regulated perimeter (and operate as described above) or outside the regulated perimeter (and operate as a shadow bank). Unlike regulated banks, shadow banks do not have to comply with the capital requirements or deposit rate ceiling set by the regulator (ie may choose $k_j < q(k_j + d_j)$ and/or $s_j > s_R$). While shadow banks may gain a competitive advantage by not complying with regulation, there are two reasons why banks may choose to remain in the regulated perimeter. First, depositor funds held by shadow banks are not covered by deposit insurance so depositors are not willing to deposit funds with shadow banks unless they offer a higher deposit rate than regulated banks. Second, depositors may find it harder to access shadow banks (for reasons described in more detail below) and, hence, the potential pool of deposits available to shadow banks is smaller. Since depositors cannot monitor risk taking, shadow banks (i) never choose to raise costly capital (i.e., always choose $k_j = 0$), and (ii) always invest solely in the high-risk projects (i.e., always choose $\theta_j^H = a_j$).

Depositors find it harder to access banks either because shadow banks (i) only serve sophisticated depositors with a high net-wealth, (ii) only serve depositors who can demonstrate a certain level of financial sophistication or (iii) face greater restrictions when trying to promote themselves to depositors. To capture this, we assume only a fraction $\lambda_A < 1$ of active depositors can access shadow banks.[15] Throughout we assume all depositors are risk neutral.[16] Since active depositors only deposit funds at banks offering the highest expected return, it follows that all shadow banks offer the same deposit rate s_{sb}. Furthermore, $s_{sb} = s_c + \Delta_{sb}$ where Δ_{sb} satisfies the following equation:

$$p\Delta_{sb} = (1-p)(s_c - r_L)$$

The left-hand side is the extra return depositors of shadow banks receive when the high-risk projects succeed (compared to the depositors of regulated competitive banks). The right-hand side captures the loss depositors of shadow banks suffer when the high-risk projects fail (compared to the depositors of regulated banks). This ensures that depositors at regulated competitive banks and shadow banks both earn an expected return of s_c. We now state a result which provides conditions under which shadow banks emerge:

Proposition 4.1 *If the return when the risky project fails is sufficiently high (i.e., $r_L > r_L^*$), then shadow banks operate alongside regulated banks. Moreover, if the returns of the risky project are sufficiently low (i.e., $r_L < \underline{r}_L^*$), then all banks remain inside the regulated perimeter.*

When the losses associated with the failure of the risky project are very high (i.e., $r_L < \underline{r}_L^*$), then the premium Δ_{sb} that shadow banks must pay depositors is also very high, and so all banks remain within the regulated perimeter. On the other hand, if the losses associated with the failure of the risky project are small (ie $r_L > r_L^*$), then the premium Δ_{sb} is also small and in this case some banks choose

[15] Note, we assume no passive depositors can access shadow banks. All our results would still hold if a proportion λ_P of depositors can access shadow banks as long as λ_P is sufficiently small. In particular, (i) $\lambda_P < \lambda_A$ (i.e., a greater proportion of active depositors can access shadow banks) and (ii) $\lambda_P < \lambda^*$ where $r_L - (1-q)s_0 - qc_0 = \lambda_P^*(r_L - s_0)$ (ensuring shadow banks do not target only passive depositors).

[16] Note, that very risk averse depositors will never deposit funds in shadow banks because funds deposited in these banks are not covered by deposit insurance. Hence, the modelling assumptions discussed also capture the scenario where all depositors can access shadow banks and (i) a fraction λ_A (λ_P) of active (passive) depositors are risk neutral (so consider depositing funds in shadow banks) and (ii) the remaining depositors are very risk averse (so always deposit funds in regulated banks).

to leave the regulated perimeter and become shadow banks. In particular, when r_L is sufficiently high then,

$$q(c_0 - p\overline{r}_H) > (1-p)(s_c - r_L) = p\Delta_{sb}.$$

Note the left-hand side of the equation captures the benefit shadow banks enjoy from holding less capital. The right-hand side of the equation captures the deposit rate premium that shadow banks must offer to their depositors. Either (i) all competitive banks will choose to be shadow banks or (ii) all competitive banks choose to be regulated. In both cases competitive banks operate alongside regulated monopolists. For an intermediate range of parameter values (i.e., $r_L \in [\underline{r}_L^*, r_L^*]$), there are multiple equilibria. This is due to the fact that as s_c decreases, regulated competitive banks move to the shadow sector and this creates strategic complementarity: if the left-hand side of the inequality is greater, then all competitive banks choose to be regulated (in which case no regulated competitive bank has an incentive to deviate); if the right-hand side of the inequality is greater, then all competitive banks choose to be shadow banks (in which case no shadow bank has an incentive to deviate). We now consider the impact of making the shadow banking sector more accessible.

Proposition 4.2 *Suppose capital requirements are sufficiently high (i.e., $q \geq q^m_{HL}$ and the losses associated with the failure of the high-risk projects are not too severe (i.e., $r_L^* < r_L < s_0$). If the shadow banking sector becomes marginally more accessible (i.e., λ_A increases to λ'_A) then,*

1. *The proportion of funds invested in high-risk projects decreases*
2. *The total amount of costly capital raised decreases*
3. *Bank profitability increases*
4. *Expected payments made by the deposit insurance scheme fall*
5. *The expected return of active depositors (i.e., s_c) falls.*

Proposition 4.2 shows that making the shadow banking sector more accessible to active depositors can both reduce the amount of capital in the banking sector and also reduce the overall level of risk taking. We first explain why (i) overall risk taking decreases and (ii) bank profitability increases. When λ_A increases, more depositors can access the shadow banking sector which, in turn, increases the proportion of banks who choose to operate outside the regulated perimeter. The remaining regulated banks face less intense competition for those depositors who cannot access shadow banks, and hence the profitability of all regulated banks (both monopolistic and competitive) increases. However, this increase in the proportion of shadow banking benefits monopolistic regulated banks more than competitive regulated banks, since although both types of banks increase their share of passive depositors by the same amount, monopolistic regulated banks (who pay a lower deposit rate) earn a higher margin on each additional passive depositor compared to competitive regulated banks (who pay a higher deposit rate). This differential impact ensures that monopolistic banks are more likely than competitive banks to remain within the regulated perimeter, and hence the proportion of passive depositors served by monopolistic banks increases. It follows that the proportion of funds invested in low-risk projects increases, since monopolistic banks (who now hold more depositor funds) solely invest in low-risk projects and other banks solely invest in high-risk projects. Finally, note that (iii) the increase in the proportion of shadow banks reduces the total amount of capital raised, (iv) the decrease in the proportion of regulated competitive banks reduces the cost of the deposit insurance scheme and (v) the increase in profitability of regulated competitive banks implies that they hold more deposits. This final effect causes regulated competitive banks to offer active depositors a lower deposit rate since a larger footprint reduces their marginal return on assets and their ability to offer depositors a high deposit rate. A proof of this result can be found in the Appendix.

5 Conclusions and policy implications

The main contribution of the paper is founded on two basic notions.

One is that Open Banking will create very strong competition for the deposits of those depositors who adopt Open Banking (creating competitive banks engaged in Bertrand competition to capture these deposits) and minimal (monopolistic) competition for "captive" customers who do not adopt open banking. Banks can choose which type of bank they wish to be, hence, although competitive banks may adopt a riskier strategy than monopolistic banks, at the margin the profit from being a competitive bank must be the same as from being a monopolistic bank.

The second is that the system wide impact of any policy change cannot be judged by the impact on a typical monopolistic or competitive bank. What also crucially matters is the impact on the relative profitability of the two types of banks. Differential impact will lead banks to move from one type to another, and this will impact the overall risk, which can offset the original purpose of the policy.

The paper considers examples of this. An increase in capital requirements bites less on the profits of competitive banks (where the market price of deposits can adjust) than monopolistic banks, who are already giving captive depositors a low deposit rate. As a result, at the margin, banks prefer to leave the (safer) monopolistic sector and move to the (riskier) competitive sector, which raises overall risk. Unless this is sufficiently offset by a reduction in risk choices of banks, the net effect will be higher risk in the system.

Another example concerns deposit rate ceilings. A deposit rate ceiling impacts the banks offering the highest deposit rates (i.e., the competitive sector). The ceiling dampens the impact of Bertrand competition on competitive deposit rates, making competitive banks more profitable. At the margin, banks prefer to leave the (safer) monopolistic sector and move to the (riskier) competitive sector so, rather than making the system more stable, a marginal increase in a deposit rate ceiling can increase risk.

Similarly, increasing the size of the shadow banking sector can positively impact the profits of monopolistic banks relative to competitive banks. This is because monopolistic banks offer the lowest deposit rates, thus gain more from any extra customers that choose to deposit with them because they have decided to leave banks that become shadow banks (e.g., because the customers are particularly risk averse compared to the average or for other reasons). At the margin, this encourages some competitive banks to become monopolistic banks, reducing overall risk and reducing the calls on the deposit insurance scheme. Thus, growing the shadow banking sector can reduce overall risk in the system.

Finally, the presence of competitive banks combined with the inability of regulators to distinguish between banks' risk-taking strategies, creates a negative externality for monopolistic banks and their low-risk investments. The levels of capital needed to persuade competitive banks to stop investing in riskier projects may take low-risk private sector projects out of the equation, with all banks choosing instead to invest in sovereign debt. This is because a high capital requirement makes sovereign debt (low-risk, identifiable and with no capital requirement) the preferred investment for all banks, so banks stop funding the private sector. The central assumption here is that sovereign debt is observable and that the risk cannot be manipulated by banks.

Our model assumes an extreme position, as common in the literature, that the regulator cannot observe whether banks invest in low-risk or high-risk private sector projects. Hence, although all banks are regulated, the regulator cannot make capital requirements dependent on a bank's risk profile.[17] Furthermore, we have adopted a simple model where, because of Open Banking, banks must decide whether to take advantage of their captured depositor base (i.e., offer low deposit rates) or compete (i.e., offer higher deposit rates) to attract deposits from those using Open Banking. We also assume that all banks are ex-ante identical. For these reasons there are only two deposit rates in the economy. Hence, in theory at least, it is plausible that in such a world the level of deposit rates might be observable by the regulator.

Although it may seem untenable in practice, the only workable solution may be to calibrate capital ratios based on the cost of funding on the liability side, even though they are aimed at tackling risk taking on the asset side. Where such a strategy is feasible, then our results imply that Open Banking is likely to exacerbate tensions between competition policy and safety and soundness, since it gives rise to a trade-off between the public objectives to promote competition and to prevent financial instability. In a more complex world, however (e.g., where depositors and banks are not identically placed and banks also offer a diversity of services and products), banks' cost of funding may be similarly difficult to observe, thus may be no easier to use as a base for setting capital requirements.

There are simple policy implications arising from our results. One, and the most obvious, is that assessing the impact of a policy change may depend just as much on differences between the relative

[17] The problems of correctly identifying differences in risk are discussed frequently in various contexts in the literature (e.g., Begley *et al.* (2017), Behn *et al.* (2022), Colliard (2019), and Eufinger & Gill (2017).

impact on sectors of the market (and the associated impact on incentives to shift activity between regulated entities), as the traditional focus on the impact on individual intermediary behavior.

Another concerns the choice of capital requirements. The paper suggests that when Open Banking levels are comparatively low, then the best strategy (in the sense of giving highest welfare) is to choose the lowest capital requirement that incentivizes monopolistic banks to invest in low-risk projects.[18] The monopolistic banks co-exist with competitive banks who invest in high-risk projects. The competitive sector, however, will be relatively small (because Open Banking levels are comparatively low) hence the welfare cost arising from their investment in high-risk projects is small relative to the cost of implementing a higher capital requirement to stop them. In this case, competitive banks are incentivised to remain in the regulatory perimeter and do not move into the shadow banking sector.

However, if Open Banking is larger, then regulators will need to address the cost of the risky choices made by competitive banks and higher capital requirements become optimal. This can happen through one of two channels (depending on parameters of the model). One is that the higher capital requirement may lead competitive banks to leave the regulated perimeter and become shadow banks. Despite the higher capital requirements, this is a better outcome because the high capital requirements encourage some competitive banks to join the monopolistic sector (reducing aggregate risk) and the other competitive banks to become shadow banks (so there is less capital needed in the system and there is less call on insurance deposits). The interesting policy implication is that, to achieve the desired outcome, all banks within the regulatory perimeter will be required to hold more capital than is necessary to incentivise them to invest in low-risk projects. The binding constraint is that capital needs to be set at the minimum level that ensures it is unattractive for competitive shadow banks to enter the regulatory perimeter. Thus, the optimal choice of capital is driven by the business model of those outside of the regulatory perimeter rather than the business model of those that are being regulated. This suggests that there may be exceptions to the view that application of international standards is sufficient.

A second alternative channel is when the optimal higher capital requirements incentivise competitive banks to stop investing in risky assets and invest in sovereign debt instead. Monopolistic banks are incentivised to switch to investing in sovereign funds instead of low-risk projects at a lower level of capital requirement than the level needed to incentivise competitive banks to invest in the sovereign bonds. So, if the optimal solution to deal with risk taking by competitive banks is to drive them into sovereign debt, then all banks will invest only in sovereign debt, i.e., there is no lending to the private sector. There is a long-standing debate around what risk weights are appropriate to attach to sovereign debt (in many jurisdictions, domestic-currency sovereign debt carries zero risk weight, e.g., see BIS (2017)). The debate has mostly focused on whether there is a subsidy to sovereign debt (e.g., zero-risk weight may not be consistent with the underlying risk) and what are the consequences

[18] Welfare is defined as the (unweighted) sum of expected consumer surplus, expected profits, expected cost of deposit insurance. Maximizing welfare is equivalent to maximizing the expected return on total assets less the return of depositors' and shareholders' outside options.

of this (e.g., Altavilla *et al.* (2017), Bouis (2019), Kirschenmann *et al.* (2020)). However, as we show, it may be optimal to adopt a risk weight for sovereign debt that is greater t 100780optimal to set a zero risk weight.

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6 Appendix

First, we define all thresholds stated in the text:

The threshold $\overline{q}_{HL}^{m}$ is defined as:

$$\underline{r}_L - (1 - \overline{q}_{HL}^{m})s_0 = p\Big(\overline{r}_H - (1 - \overline{q}_{HL}^{m})s_0\Big);$$

the threshold $\underline{q}_{HL}^{c}$ is defined as:

$$\overline{r}_L - \underline{q}_{HL}^{c} c_0 = \underline{r}_H - \underline{q}_{HL}^{c} c_0/p;$$

the threshold $\overline{q}_{LB}$ is defined as:

$$\underline{r}_B = \overline{r}_L - \overline{q}_{LB}(c_0 - \overline{r}_L);$$

The threshold $\underline{q}_{LB}$ is defined as:

$$\overline{r}_B = \underline{r}_L - \underline{q}_{LB}(c_0 - \underline{r}_L);$$

the threshold $r_B^{\min}$ is defined as:

$$r_B^{\min} = \overline{r}_L - \frac{p(\underline{r}_H - \overline{r}_L)}{(1-p)(\overline{r}_L - \underline{r}_B)}.$$

We define $\underline{s}_0$ as:

$$\underline{s}_0 = \frac{\overline{r}_L - p\underline{r}_H}{1-p},$$

$\overline{s}_0$ (and K_A) as:

$$\overline{s}_0 = \left[\frac{c_0 - \underline{r}_L}{\underline{r}_L - \overline{r}_B}\right] \Bigg/ \left[\frac{(\overline{r}_L - p\underline{r}_H) - (\underline{r}_L - p\overline{r}_H)}{(\overline{r}_L - p\underline{r}_H)}\right] \underline{s}_0 = K_A \underline{s}_0$$

and $\underline{c}_0^{(A)}$ to satisfy the following equation:

$$\left[\frac{\underline{c}_0^{(A)} - \underline{r}_L}{\underline{r}_L - \overline{r}_B}\right] \Bigg/ \left[\frac{(\overline{r}_L - p\underline{r}_H) - (\underline{r}_L - p\overline{r}_H)}{(\overline{r}_L - p\underline{r}_H)}\right] = 1.$$

Note, that when $c_0 > \underline{c}_0^{(A)}$, then (i) $K_A > 1$ and, hence, (ii) $\overline{s}_0 > \underline{s}_0$.

We define $K_B = \frac{p(\underline{r}_H - \overline{r}_L)}{(1-p)(\overline{r}_L - \underline{r}_B)}$ and $\underline{c}_0^{(B)}$ as follows:

$$\underline{c}_0^{(B)} = \frac{\overline{r}_L}{K_B - 1}.$$

Note, that when $\underline{r}_B > r_B^{\min}$, then (i) $K_B > 1$ and, hence, (ii) $\underline{c}_0^{(B)} > 0$.

Finally, we define $\underline{c}_0 = \max\left\{\underline{c}_0^{(A)}, \underline{c}_0^{(B)}\right\}$.

Lemma 6.1 *Banks either invest in (i) only risky projects or (ii) a combination of safe projects and government bonds.*

Discussed in the main body of the a paper.

Lemma 6.2 *If $q < \underline{q}_{LB}$, banks do not invest in government bonds. If $q > \overline{q}_{LB}$, banks do not invest in safe projects.*

Discussed in the main body of the a paper.

Lemma 6.3 *If $q \in (\overline{q}_{LH}, \underline{q}_{LB})$, then monopolistic banks invest only in safe projects. Meanwhile if $q < \underline{q}^c_{LH}$ competitive banks do not invest in safe projects.*

Discussed in the main body of the a paper.

Lemma 6.4 *If $r_B^{\min} < \underline{r}_B < \overline{r}_B < \underline{r}_L$ and $c_0 > \underline{c}_0$, then $\overline{q}_{LB} < \underline{q}^c_{HL}$.*

Recall that:

$$\underline{r}_B = \overline{r}_L - \overline{q}_{LB}(c_0 - \overline{r}_L),$$

and

$$\overline{r}_L - \underline{q}^c_{HL} c_0 = \underline{r}_H - \underline{q}^c_{HL} c_0/p.$$

Rearranging these equations gives:

$$\overline{q}_{LB} = \frac{\overline{r}_L - \underline{r}_B}{c_0 - \overline{r}_L},$$

and

$$\underline{q}^c_{HL} = \frac{p(\underline{r}_H - \overline{r}_L)}{c_0(1-p)}.$$

Dividing the second by the first gives:

$$\frac{\underline{q}^c_{HL}}{\overline{q}_{LB}} = \frac{p(\underline{r}_H - \overline{r}_L)}{(1-p)(\overline{r}_L - \underline{r}_B)} \frac{c_0 - \overline{r}_L}{c_0}.$$

Now, recall that $c_0 > \underline{c}_0$ and (since $\underline{r}_B > r_B^{\min}$) $K_c = \frac{p(\underline{r}_H - \overline{r}_L)}{(1-p)(\overline{r}_L - \underline{r}_B)} > 1$. Hence,

$$\frac{\underline{q}^c_{HL}}{\overline{q}_{LB}} > K_c \frac{\underline{c}_0 - \overline{r}_L}{\underline{c}_0} = K_c - \frac{K\overline{r}_L}{\underline{c}_0}.$$

Recall that $\underline{c}_0 = K_c \overline{r}_L/(K_c - 1)$ and so $K\overline{r}_L/\underline{c}_0 = K_c - 1$. It follows that

$$\frac{\underline{q}^c_{HL}}{\overline{q}_{LB}} > K_c - \frac{K_c \overline{r}_L}{\underline{c}_0} = K_c - (K_c - 1) = 1.$$

Hence, $\frac{\underline{q}^c_{HL}}{\overline{q}_{LB}} > 1$ and $\underline{q}^c_{HL} > \overline{q}_{LB}$.

Lemma 6.5 *If $s_0 > \underline{s}_0$, then $\overline{q}^m_{HL} > 0$.*

Recall that

$$\underline{r}_L - (1 - \overline{q}^m_{HL})s_0 = p\Big(\overline{r}_H - (1 - \overline{q}^m_{HL})s_0\Big).$$

Rearranging it gives

$$\overline{q}^m_{HL} = \frac{(1-p)s_0 - (\underline{r}_L - p\overline{r}_H)}{(1-p)s_0}.$$

Recall that $s_0 > \underline{s}_0 = \frac{\overline{r}_L - p\underline{r}_H}{1-p}$ and, hence, $(1-p)s_0 > \overline{r}_L - p\underline{r}_H$. Using this inequality yields

$$\overline{q}^m_{HL} > \frac{(\overline{r}_L - p\underline{r}_H) - (\underline{r}_L - p\overline{r}_H)}{(\overline{r}_L - p\underline{r}_H)}.$$

Since (i) $\overline{r}_L > \underline{r}_L$, (ii) $\overline{r}_H > \underline{r}_H$, and (iii) $\overline{r}_L > p\underline{r}_H$, it follows that $\overline{q}^m_{HL} > 0$.

Lemma 6.6 *If $s_0 < \overline{s}_0$, then $\overline{q}^m_{HL} < \underline{q}_{LB}$.*

Recall that:

$$\underline{r}_L - (1 - \overline{q}^m_{HL})s_0 = p\Big(\overline{r}_H - (1 - \overline{q}^m_{HL})s_0\Big),$$

and

$$\overline{r}_B = \underline{r}_L - \underline{q}_{LB}(c_0 - \underline{r}_L).$$

Rearranging them gives

$$\underline{q}_{LB} = \frac{\underline{r}_L - \overline{r}_B}{c_0 - \underline{r}_L},$$

and

$$\overline{q}^m_{HL} = \frac{(1-p)s_0 - (\underline{r}_L - p\overline{r}_H)}{(1-p)s_0}.$$

Recall that $s_0 < \overline{s}_0 = K_s \underline{s}_0$, where $K_s > 1$. Using this inequality yields

$$\overline{q}^m_{HL} < K_s\left[\frac{(\overline{r}_L - p\underline{r}_H) - (\underline{r}_L - p\overline{r}_H)}{(\overline{r}_L - p\underline{r}_H)}\right].$$

Hence,

$$\frac{\overline{q}^m_{HL}}{\underline{q}_{LB}} < K_s\left[\frac{(\overline{r}_L - p\underline{r}_H) - (\underline{r}_L - p\overline{r}_H)}{(\overline{r}_L - p\underline{r}_H)}\right]\left[\frac{c_0 - \underline{r}_L}{\underline{r}_L - \overline{r}_B}\right].$$

Recall that

$$K_s = \left[\frac{(\overline{r}_L - p\underline{r}_H)}{(\overline{r}_L - p\underline{r}_H) - (\underline{r}_L - p\overline{r}_H)}\right]\left[\frac{\underline{r}_L - \overline{r}_B}{c_0 - \underline{r}_L}\right].$$

Hence, $\frac{\overline{q}^m_{HL}}{\underline{q}_{LB}} < 1$ and so $\overline{q}^m_{HL} < \underline{q}_{LB}$.

Proposition 6.7 *Suppose that* $s_0 < \overline{s}_0$, $r_B^{\min} < \underline{r}_B < \overline{r}_B < \underline{r}_L$ *and* $c_0 > \underline{c}_0$. *Then,* $0 < \overline{q}_{HL}^m < \underline{q}_{LB} < \underline{q}_{HL}^c$.

Suppose that $s_0 < \overline{s}_0$, $r_B^{\min} < \underline{r}_B < \overline{r}_B < \underline{r}_L$ and $c_0 > \underline{c}_0$. Then, it follows from lemmas 6.4, 6.5, 6.6 that (i) $0 < \overline{q}_{HL}^m$, (ii) $\overline{q}_{HL}^m < \underline{q}_{LB}$, and (iii) $\overline{q}_{LB} < \underline{q}_{HL}^c$. Furthermore, it follows from the threshold definitions that (iv) $\underline{q}_{LB} < \overline{q}_{LB}$. Given (i) to (iv), it follows that $\overline{q}_{HL}^m < \underline{q}_{LB} < \underline{q}_{HL}^c$. Hence, it follows from 6.2 and 6.3 that whenever $q \in (q_{HL}^m, q_{LB})$, monopolistic banks invest in safe projects and competitive banks invest in risky projects.