Open Banking and Capital Requirements *

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Abstract

We provide a model where some consumers can observe and act on all deposit rates in the market and others cannot (motivated by open banking and other fintech solutions). We show that this leads to diverse business models in the market, monopolistic banks (taking advantage of their monopoly footprint) and those taking advantage of the new technology. Capital requirements need to take account of their impact on the attractiveness of the different sectors. We show that this additional effect, of banks moving sector, can offset the traditional impact of capital requirements, so that higher capital requirements can increase overall risk-taking. Policy implications are discussed.

JEL-Classification: D43, G21, G28

1 Introduction

”Open banking”, is a generic term used to define an emerging fintech financial services model where third parties are allowed to obtain (with the individuals approval) access to the individuals accounts and payments systems, allowing the third parties to offer financial products direct to, and invest on behalf of, those customers of another banks customer base that have given approval. The model is being pushed, at different degrees of speed, by regulatory authorities throughout the world (e.g., UK, US, EU, Canada, Australia, India, Japan) as a way to allow access (usually through an application programming interface) to customers credit histories to enable third parties to offer focused services and hence

*The views expressed are those of the authors and do not necessarily reflect those of the Bank of England. Email addresses: Peter.Eccles@bankofengland.co.uk, p.a.grout@bristol.ac.uk, Paolo.Siciliani@bankofengland.co.uk create greater competition in banking services and financial markets. The mix of the new competitive environment generated by banks taking advantage of open banking alongside traditional monopolist banks (taking advantage of their monopoly footprint) raises interesting questions for banking regulation. This paper studies the implications of open banking for capital requirements, when the impact of any change in capital requirement on the relative attractiveness of the two sectors is recognised.

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 is well understood, and that unregulated competition may be sub-optimal: Keeley (1990); Matutes & Vives (2000); Allen & Gale (2004) and Freixes & Rochet (2008)).[1] Less so is whether the optimal response from a regulatory perspective is to increase minimum capital requirements. Hellman *et al.* (2000) find that although higher capital requirements tend to mitigate the limited liability effect identified by Jensen (1976) in the static game (ie, *skin-in-the-game* effect), they also dilute the franchise value of banks in a dynamic fashion (ie, *gambling* effect). In contrast, Repullo (2004) shows that banks may be able to pass on the common increase in costs due to higher capital requirements to depositors by reducing rates. Therefore, there is no erosion of banks' franchise values so that only the *skin-in-the-game* effect is at work.

We add to this line of inquiry by developing a model that yields a diversity of business models in that banks play different strategies on both sides of their balance sheets, that is, notwithstanding the fact that banks are symmetric to start with. First of all, on the liability side, banks can either set a very low rate and only raise deposits from captured depositors who are inactive and do not shop around, or set a very high rate in order to also compete for active depositors who do not exhibit a preference towards any specific bank so that they are merely interested in getting the highest rate. We believe that this partition better reflects the state of play in mature retail banking markets and the expected impact of interventions by conduct and competition authorities aimed at spurring consumer shopping around and switching. For example, the UK competition authority imposed Open Banking, a technological platform that supports the use of third-party digital shopping assistants (labelled aggregators), through the adoption of standard application programme interfaces (APIs), with the aim of reversing the persistent low level of switching activity due to consumer disengagement.[2] Specifically, the Competition and

[1] A different strand of literature analyses the financial stability implications of banking competition in lending: see, for example, Perotti & Suarez (2002); Boyd & De Nicolo (2005); Martinez-Miera & Repullo (2010); Schliephake (2016) and Arping (2017).

[2] CMA paves the way for Open Banking revolution, 9 August 2016, available at https://www.gov.uk/government/news/cma-paves-the-way-for-open-banking-revolution. In addition, the importance attributed to the presence of an extensive branch network is diminishing as online banking becomes the most prominent distribution channel: see, for example, Edmonds, T., Bank branch closures, House of Commons Library Briefing Paper No. 385, 19 October 2018, available at http://researchbriefings.files.parliament.uk/documents/SN00385/SN00385.pdf

Markets Authority required the six largest incumbent deposit-taking institutions to adopt a common APIs through which they will share data with third party service providers including price comparison websites, account information service providers (ie, aggregators) and payment initiation service providers which allow consumers to seamlessly instruct their bank to make a payment directly from third-party online applications. The last two types of service providers were introduced under the revised EU Payment Services Directive which also came into force in January 2018 with the same kind of access remedy in favour of third-parties.

A year on from the launch in January 2018, up to 100 regulated providers are using this platform with 67 being third-party providers.[3] Whilst so far Open Banking has only covered personal current accounts, it is soon to be extended to cash savings accounts as well. It is worth noting that Open Banking is also being implemented in Hong Kong from July 2018 and Australia from July 2019, with many other jurisdiction potentially following suit (e.g., US, Singapore, Japan, India, New Zealand, Canada, South Korea, Brazil, Israel, Malaysia and Taiwan) [4] By the same token, enhanced solutions, such as the recent proposal for identity portability that would encompass a broader set of personal data, may further reduce the switching (hassle) costs involved in opening a new bank account related to know-your-customer (KYC) checks. Accordingly, depending on the level of adoption, there can be two cohorts of consumers behaving in radically opposite ways.

This partition between active and inactive retail depositors is in line with the distinction between informed and uninformed buyers due to the presence of heterogenous search costs introduced to model the persistence of price dispersion for homogenous goods (Salop & Stiglitz (1977) and Varian (1980)). The same approach was then adopted to model the exploitation of behavioural biases affecting nave consumers, in contrast to sophisticated ones (eg, Gabaix & Laibson (2006) and Heidhues & Koszegi (2017)).[5].

Open Banking is aimed to address both sources of demand-side frictions. Regarding search costs, thanks to APIs aggregators can seamlessly gain access, with the users consent, to detailed information on a users consumption profile eg, average credit balance and number

[3] Open Banking technology was used 17.5 million times in November last year, up from 13.9 million in October and 6.5million in September, with Application Programming Interface (API) calls now having a success rate of 97.7 per cent: see https://www.openbanking.org.uk/providers/account-providers/api-performance

[4] See Deloitte, Open Banking around the world: towards a cross-industry data sharing ecosystem, available at https://blogs.deloitte.co.uk/financialservices/2018/11/open-banking-around-the-world-towards-a-cross-industry-data-sharing-ecosystem.html; and also Bill Roberts (Head of Open Banking at the CMA, Celebrating the first anniversary of Open Banking, available at https://competitionandmarkets.blog.gov.uk/2019/01/11/open-banking-anniversary/

[5] With respect to personal current accounts, exploitation of naive customers may be the result of high charges for the use of overdrafts which sophisticated consumers are able to avoid (Armstrong & Vickers (2012))

of transactions per month which can then be mapped against all the available tariffs in order to provide a bespoke comparison advice ie, regardless of tariff complexity. With respect to naivety, Open Banking supports applications that monitor usage profile in order to assist consumers to better manage their finances over multiple accounts, not only through customised alerts and prompts, but also by directly instructing payments. The potential impact of Open Banking would be magnified were Internet giants such as Google, Amazon, Facebook, and Apple (collectively labelled as GAFAs)[6] to decide to step into the fray, that is, thanks to their large customer base and trusted brands.[7]

Besides the immediate impact under Open Banking due to the increased pricing rivalry for sight deposits, the cost of funding could also increase as firms replace them with fixed term deposits which are typically remunerated at a higher rate. Firms may be required to change their funding mix to stay compliant with Basel rules on liquidity adequacy,[8] to the extent that sight deposits become more flighty (ie, in contrast to their current behavioural stability) in response to consumers increased propensity to shop around and switch.

The separation in terms of bank strategies on the liability side, creating monopolistic and competitive banks, leads in turn to a separation in terms of lending strategies on the asset side of banks' balance sheets, where, as standard in the literature, banks can choose between a safe type of asset and a risky one, with the former dominating in terms of expected return. The combination of these binary strategies on the two balance sheet sides generates four types of business models in principle: (i) the safe monopolistic bank; (ii) the risky monopolistic bank; (iii) the safe competitive bank; and (iv) the risky competitive bank. Under this configuration, the welfare impact of an increase in capital requirements is the combined result of three separate effects, one of which is new. First, there is the standard skin-in-the-game effect that reduces moral hazard due to the limited liability protection under the deposit guarantee scheme. This effect tends to induce banks that adopted a risky lending strategy to become prudent by investing in the safe asset. However, because of the *pass-through* effect identified by Repullo (2004), those banks competing for active depositors are unaffected by the increase in capital requirement, thanks to the

[6]There also is an acronym covering Chinese peers: Baidu, Alibaba, and Tencent (BAT).

[7]See, for example, Nicholas Megaw and Rochelle Toplensky, Santander Chair Calls EU Rules on Payments Unfair Financial Times (London, 17 April 2018), available at https://www.ft.com/content/d9f819f2-3f39-11e8-b7e0-52972418fec4.

[8]For the purpose of the liquidity coverage ratio, retail deposits are divided into stable and less stable portions of funds, with minimum run-off rates listed for each category. The run-off rates for retail deposits are minimum floors, with higher run-off rates established by individual jurisdictions as appropriate to capture depositor behaviour in a period of stress in each jurisdiction. Stable deposits, which usually receive a run-off factor of 5%, are the amount of the deposits that are fully insured by an effective deposit insurance scheme or by a public guarantee that provides equivalent protection and where: (i) the depositors have other established relationships with the bank that make deposit withdrawal highly unlikely; or (ii) the deposits are in transactional accounts (eg accounts where salaries are automatically deposited).

fact that they can compensate for it by lowering the competitively-set deposit rates. In contrast, monopolistic banks cannot do the same, given that they are already offering the lowest possible deposit rate to captured consumers. Hence the increase in capital requirement bites on monopolistic safe firms, reducing their profitability.

The combined effect of declining profit for monopolistic banks and the pass-through effect for competitive firms implies that an increase in capital requirement makes the competitive market more attractive at the margin for monopolistic banks. As a result, some firms change business model by becoming a competitive risky banks instead. This incentive to move from the monopolistic sector to the competitive sector is a novel effect which works in the opposite direction to the traditional impact of capital requirements on risk taking. In some regards it is similar to the *gambling* effect in Hellman *et al.* (2000), in the sense that it identifies another counterproductive transmission channel. However, the effect we identify is static in nature. Hence it does not have to rely on the franchise value of banks or the change in capital requirements being permanent.

The fact that changes in capital requirements impact on the incentives of monopolistic banks to become competitive (risky) banks is at the heart of the main results of the paper. One concerns the relationship between capital requirements and aggregate risk taking. As indicated, increasing capital requirements hurts monopolistic banks more than competitive banks and hence encourages some monopolistic banks to become competitive. Since the higher deposit rates in the competitive market implies competitive banks are more risky than the monopolistic banks then this shift from monopolistic sector to competitive sector is a source of additional risk which reduces the conventional risk reduction effect. We show (see Section 4 below) that it is feasible for this risk enhancing effect to be so large as to reverse the conventional relationship between risk and capital requirements. That is, the increase in risk arising from the shift in banks from the monopolistic sector to the competitive sector is greater than the reduction in risk of banks that do not change sector and hence increasing capital requirements can lead to greater risk in the system rather than less.

A second result concerns the implications for capital requirements. Since capital requirements are passed-through in the competitive sector (hence the risk reducing properties of capital requirements are weak in this sector) and higher capital requirements make the competitive market more attractive for banks, then capital requirements need to be very high if they are to reduce risk taking. On the other hand, very high capital requirements are expensive and hence unattractive. So, it may be that the social cost of achieving low risk is deemed too high. In this case the capital requirements are likely to be low since moderate increases in capital requirement raise costs to banks but achieve little in the way of risk reduction. This shows that there is no simple answer to the question as to what will be the effect of fintech solutions, such as open banking, on capital requirements. The above provides the basic intuition and in Section 2 we provide a specific model that shows these forces at work. The model suggests that there are likely to be significant effects, but that these could take the form of a considerable increase in capital requirements or a considerable fall. The results have interesting policy implications that are discussed in Section 5.

Expanding on the relationship between our paper and the existing literature, note that Hellman *et al.* (2000) model competition for insured deposit in a reduced form way, by assuming that the overall amount of deposit a bank can collect is increasing in the bank's own interest rate and decreasing in the competitors' rate. In contrast, Repullo (2004) develop a fully-fledged model of competition based on the framework of horizontal differentiation introduced in Salop (1979) where a finite number of firms are symmetrically distributed along a circle representing a normalised mass of depositors that are uniformly distributed and face a common preference disutility parameter which is multiplied by the distance away from the location of a firm (labelled transport cost). Therefore, consumers who are further away from firms location are more willing to switch, so that the higher the number of firms the more intense competition will be. However, marginal consumers end up paying the highest prices (ie, inclusive of transport cost), which tends to soften pricing rivalry, that is, compared to a scenario where marginal consumers do not have any brand preference at all.[9] In contrast, we model Bertrand price competition for active depositors, which is why firms are faced with a binary decision between exploiting only captured depositors and competing also for active ones.

Our model closely follows Hellman *et al.* (2000) and Repullo (2004) with respect to the way banks lending activity is modelled. There are two options, one asset yielding a certain return that on expectation is superior to the uncertain return from the other option, although the expected (private) return for banks owners yielded by the latter are higher, thanks to the fact that they are protected from the downside risk. The regulator cannot observe banks choices, so that it cannot set higher capital requirements to address banks moral hazard. We also assume the expected return of each asset decreases as the volume invested increases. This feature is meant to capture the idea that increasing volumes of lending would ultimately tend to put downward pressure on the return of any particular asset class. This can be the result of pricing pressure due to the relative scarcity of the asset in question, or the fact that banks decide to weaken their underwriting standards in order to grow the volume of lending. [10] We consider the case where the market for

[9] Similarly, in Allen & Gale (2004) and Boyd & De Nicolo (2005) banks compete by setting quantities (ie, la Cournot), which also tends to soften pricing rivalry notwithstanding the fact that consumers perceived available products as homogeneous.

[10] Dell'Ariccia (2006) show how a reduction in lending standards can be triggered by an expansion in the demand for credit, rather than from the supply-side. During the expansionary phase of a business cycle the make-up of perspective

the safe asset is deeper than the market for the risky asset and hence focus on the case where (given the same increase in volume) the expected return on the risky asset falls more sharply than the expected return on the safe asset.[11]

The paper is structured as follows. The next section sets out the structure and assumptions of the model. Section 3 contains the formal analysis, outlining the existence of equilibrium, the implications for competitive and monopolistic banks, the implications for welfare, and hence the capital requirements and capital structures of banks. Section 4 provides a specific numerical example and Section 5 provides a discussion of the main results and the policy implications of the model.

2 Model

There is a continuum of risk-neutral firms indexed $j \in J$ who compete between each other to raise capital from investors and deposits from depositors. There is also a continuum of small depositors $i \in I$ who hold funds they may choose to deposit with one of the firms $j \in J$. There are two types of depositors: first there are active depositors who can access every firm; secondly there are passive depositors who can only access one firm. Let d_0 be equal to the total quantity of funds held by those passive depositors who can only access firm j. Meanwhile let $\mu \in [0, 1]$ be equal to the proportion of funds held by active depositors who can access every firm. Both active depositors and passive depositors also have the choice to invest in an outside option and obtain a return of s_0.

2.0.1 Firms raise deposits and capital

Each firm $j \in J$ chooses a deposit rate s_j. Throughout we write s^{max} to denote the highest deposit rate set by any firm $j \in J$. We assume that firms cannot segment the deposit market and must offer the same deposit rate to active and passive depositors. This feature can be the result of a non-discriminatory requirement imposed by the conduct regulator with the aim of protecting passive consumers.[12] Active depositors choose to deposit funds at one of the firms offering the highest deposit rate, namely $s^{\max}$. We assume that each firm offering deposit rate $s_j = s^{\max}$ attracts the same number of active depositors. Meanwhile passive depositors attached to firm j either (i) deposit their funds with firm

borrowers improves on average as the proportion of existing borrowers who have already been rejected by a bank is diluted thanks to the flow of new borrowers. Therefore, banks respond by lowering underwriting standards.

[11]This is in contrast to the argument in Boyd & De Nicolo (2005) that lower lending rates due to increase competition among banks may ultimately benefit them to the extent that the risk profiles of borrowers improve thanks to the ensuing lower repayment burden. However, the opposite would tend to happen when banks face advantageous selection whereby lower prices attract (marginal) borrowers with a worse credit risk profile Mahoney & Weyl (2017).

[12]For example, the UK Financial Conduct Authority is concerned about the use of price discrimination for cash savings accounts: see FCA, Price discrimination in the cash savings market, DP18/6, July 2018, available at https://www.fca.org.uk/publication/discussion/dp18-06.pdf

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 firm j from passive and active depositors.

After receiving deposits d_j, each firm then chooses to raise an amount of capital k_j from investors and hence the total assets a_j of firm j is equal to $a_j = d_j + k_j$. Investors demand an expected return c_0 from every unit of capital supplied. We assume that $c_0 > s_0$, and hence the outside option c_0 of investors in capital markets is greater than the outside option s_0 of consumers in the deposit market.

The capital ratio of firm j is equal to $q_j = k_j/a_j$. The firm must ensure its capital ratio complies with the capital requirements set by the regulator. In particular we consider the case where the regulator requires $q_j \geq q$. This means that firms must hold at least q units of capital for every unit of asset, and hence $k_j \geq qa_j$.

2.0.2 Firms invest into projects

After firms have received deposits and raised capital, each firm j simultaneously chooses to invest an amount θ_j into risky projects, where $\theta_j \in [0, a_j]$. Remaining assets $(a_j - \theta_j)$ are invested into a safe project. The safe project always returns $R^*(a_j - \theta_j)$, with $(1-q)s_o < R^* < c_0$ meaning that bank capital is costly. Meanwhile the risky project is successful with probability p and unsuccessful otherwise. Given θ_j is invested into the risky project, revenue from the risky project equals $R^H(\theta_j) > R^*(\theta_j)$ if the project is successful and $R^L(\theta_j) < R^*(\theta_j)$ otherwise. This means that total revenue $R(a_j, \theta_j)$ from the safe and risky project can be written as follows:

$$R(a_j, \theta_j) = \begin{cases} R^*(a_j - \theta_j) + R^H(\theta_j) & \text{if risky project successful} \\ R^*(a_j - \theta_j) + R^L(\theta_j) & \text{if risky project not successful} \end{cases}$$

In the case where $R(a_j, \theta_j) < (1-q)s_j$ the overall revenue firm j receives from projects is lower than the amount firm j must pay to depositors. In this case we say firm j becomes insolvent. We assume that depositors are fully insured by the regulator. This means that when firm j becomes insolvent in order to ensure depositors are fully compensated the regulator incurs a cost of $(1-q)s_j - R(a_j, \theta_j) > 0$.

2.1 Decreasing returns to scale

We assume R^*, R^H and R^L are continuous and differentiable with first derivatives r^* , r^H and r^L respectively. We assume r^*, r^H and r^L are strictly decreasing and hence both the safe and risky projects have decreasing returns to scale. We define (i) $r^*_{\max} = r^*(0)$, (ii) $r^H_{\max} = r^H(0)$ and (iii) $r^L_{\max} = r^L(0)$. Similarly we define (i) $r^*_{\min} = \lim_{\theta\to\infty} r^*(\theta)$, (ii) $r^H_{\min} = \lim_{\theta\to\infty} r^H(\theta)$ and (iii) $r^L_{\min} = \lim_{\theta\to\infty} r^L(\theta)$.

We assume that extra investment in the risky project leads to lower expected returns than extra investment in the safe project. In particular:

$$r^*_{\min} \geq pr^H_{\max} + (1-p)r^L_{\max}$$

We also make the following assumption on R^H:

$$R^H(\theta) - \theta r^H(\theta) \to \infty \text{ as } \theta \to \infty$$

We make a similar assumption on R^*:

$$R^*(\theta) - \theta r^*(\theta) \to \infty \text{ as } \theta \to \infty$$

These final two technical assumptions assume that the revenue functions decrease slowly enough that there is always sufficient room underneath the revenue curve. These technical assumptions are used to ensure equilibrium existence: without them risky competitive firms may not be able to make enough profits and no pure strategy equilibrium would exist. These technical assumptions could be replaced by a number of other mechanisms that ensure competitive firms make sufficient profit. For instance, in this model active depositors search all funds simultaneously and deposit funds at a firm offering the highest deposit rate $s^{\max}$. Weakening this assumption - for instance assuming that active depositors search sequentially and have a weak preference for the first firm they find - would be another way to ensure competitive firms make sufficient profits.

2.1.1 Firms maximization problem

Since capital is costly, firms prefer to hold as little capital as possible and hence firms choose their capital ratio such that $q_j = q$. It follows that when the risky project is successful the profits of firm j (ignoring the cost of capital) are given as follows:

$$\pi^H(a_j, \theta_j, s_j) = R^*(a_j - \theta_j) + R^H(\theta_j) - a_j(1-q)s_j$$

Similarly when the risky project is unsuccessful, the profits of firm j (ignoring the cost of capital) are given as follows:

$$\pi^L(a_j, \theta_j, s_j) = R^*(a_j - \theta_j) + R^L(\theta_j) - a_j(1-q)s_j$$

Note that the total assets a_j of firm j depends on (i) the deposit rate s_j of firm j, (ii) the deposit rates s_{-j} other firms set and (iii) the capital ratio q. This means that total assets can be written as $a_j = a_j(s_j|s_{-j}, q)$. Using this notation - and the fact that firms have limited liability - total expected profits (including the cost of capital) is given as follows:

$$u(s_j, \theta_j) = \max\left\{0, p\pi^H\Big(a_j(s_j|s_{-j}, q), \theta_j, s_j\Big)\right\} + \max\left\{0, (1-p)\pi^L\Big(a_j(s_j|s_{-j}, q)\theta_j, s_j\Big)\right\} - qc_0 a_j$$

When analysing the strategic behaviour of firms, we consider the case where firms choose their deposit rate s_j and amount to invest θ_j in order to maximize profits $u(s_j, \theta_j)$. In particular we assume firms correctly anticipate the deposit rates set by other firms, and hence firm j treats s_{-j} as given when choosing s_j and θ_j.

3 Analysis

3.1 Equilibrium existence

Define $a_0(q) = d_0/(1-q)(1-\mu)$ to be the quantity of assets each firm would have if (i) the regulator set the capital ratio equal to q and (ii) assets were shared equally among all firms. Now we define $\overline{q}$ to be the highest capital ratio the regulator can set which ensures that any firm who (i) raises a quantity of assets $a_0(q)$, (ii) sets a deposit rate $s_j = s_0$ and (iii) invests only in the safe asset remains profitable. It follows that $\overline{q}$ can be formally defined as follows:

$$\overline{q} = \max \left\{ q | R^* \Big(a_0(q) \Big) \geq (1-q)s_0 a_0(q) + q c_0 a_0(q) \right\}$$

With this definition in mind, we now state the following proposition:

Proposition 3.1 *Suppose regulator sets a capital ratio $q \leq \overline{q}$. Then there exists an equilibrium where all firms maximize profits. Moreover every capital ratio q is associated with five equilibrium values (namely a_m, a_c, γ_c, γ_m and $s^{\max}$) such that in any equilibrium:*

1. *A proportion $\gamma_c \in (0, 1]$ of firms choose deposit rate $s_j = s^{\max}$ and raise assets $a_j = a_c$*
2. *A proportion $\gamma_m = 1 - \gamma_c \in [0, 1)$ of firms choose deposit rate $s_j = s_0$ and raise assets $a_j = a_m$*
3. *All firms choose to invest either:*
   (a) *Invest fully in the safe asset (choose $\theta_j = 0$) and remain solvent with probability 1*
   (b) *Invest fully in the risky asset (choose $\theta_j = a_j$) and remain solvent with probability p*

In the following analysis we initially focus on the following: first we provide a characterisation of each of the 5 equilibrium values (namely a_m, a_c, γ_c, γ_m and s^{max}) for every value of $q \in [0, \overline{q}]$; secondly we provide conditions under which firms invest in the safe and risky asset; thirdly we examine the capital ratio q that the regulator should choose to maximize total welfare. We end this section with a discussion of how firm behaviour and the capital ratio changes as competition intensifies.

3.2 Monopolistic firms

If firm j chooses to adopt a monopolistic strategy by setting a deposit rate $s_j = s_0$, this firm will only attract passive consumers: hence $d_j = d_0$ and $a_j = d_0/(1-q)$. If the monopolistic firm only invests into the safe asset it earns revenue $R^*(a_j)$ so that depositors are always fully repaid. Meanwhile if the monopolistic firm follows a risky strategy, then with probability p the firm earns $R^H(a_j)$ and fully repays depositors. Meanwhile with probability $(1-p)$ a monopolistic firm following a risky strategy makes no profits.

It follows that a monopolistic firm following a safe strategy makes expected profits of $\pi_m^* = a_j\Big[R^*(a_j)/a_j - (1-q)s_0\Big]$, whilst following a risky strategy yields expected profits $\pi_m^H = pa_j\Big[R^H(a_j)/a_j - (1-q)s_0\Big]$. Note that since (i) monopolistic firm hold the same amount of capital $k_j = q_j a_j = qd_0/(1-q)$ and (ii) capital investors always receive c_0 in expectation per unit of capital invested, it follows that a monopolistic firm makes the same expected payment to capital investors whether or not they follow a risky strategy. We define q_m^* to be the capital ratio that ensures $\pi_m^* = \pi_m^H$ and hence it follows that:

$$q_m^* = \min\left\{q \Big| R^*\Big(\frac{d_0}{1-q}\Big) - s_0 d_0 \geq p\Big[R^H\Big(\frac{d_0}{1-q}\Big) - s_0 d_0\Big]\right\}$$

If the regulator choose a capital ratio below this threshold capital ratio (with $q < q_m^*$), then monopolistic firms will prefer to choose to invest in the risky asset. Meanwhile if the regulator chooses a capital ratio above this threshold capital ratio (with $q \geq q_m^*$) then monopolistic firms will choose to invest in the safe assets. The result below formalises this:

Proposition 3.2 *Suppose the regulator chooses $q \in [0, \overline{q}]$. Moreover suppose firm j chooses to adopt a monopolistic strategy by setting a deposit rate $s_j = s_0$. Then:*

1. *Total assets a_j of firm j are equal to $a_j = a_m(q) = d_0/(1-q)$*
2. *Profits of firm j are equal to $\pi_j = \pi_m = \max\{\pi_m^*, \pi_m^H\}$*
3. *If $q < q_m^*$ then:*
   (a) *Firm j will invest $\theta_j = a_j$ into the risky asset*
   (b) *Firm j remain solvent with probability p*
4. *If $q \geq q_m^*$ firm then:*
   (a) *Firm j will invest $\theta_j = 0$ into the risky asset*
   (b) *Firm j remain solvent with probability 1*

This result closely mirrors Proposition 1 in Hellman *et al.* (2000). The next stage of our analysis examines competitive firms who set a deposit rate $s_j > s_0$.

3.3 Competitive firms

Suppose the regulator chooses a capital ratio q and every competitive firm j raises $a_j = a_c = a_c(q)$ total assets. It follows that each competitive firm receives depositor funds $d_j = (1-q)a_c$ and of these funds (i) d_0 will be from passive depositors and (ii) $(1-q)a_c - d_0$ will be from active depositors. Since (i) a proportion $\gamma_c = \gamma_c(q)$ of firms choose to be competitive and (ii) on average each firm receives $\mu d_0/(1-\mu)$ of funds from active depositors, we can deduce that:

$$\gamma_c\Big[(1-q)a_c - d_0\Big] = \frac{\mu d_0}{1-\mu}$$

This market clearing condition ensures demand for active depositors (left hand side) equals supply of active depositors (right hand side). We now use this market clearing condition and the fact that the proportion of competitive firms $\gamma_c(q) \leq 1$ to deduce the following:

Lemma 3.3 *Suppose the regulator chooses a capital ratio $q < \overline{q}$. Then:*

$$a_c(q) \geq a_c^{min}(q) = \frac{d_0}{(1-q)(1-\mu)}$$

The strategy in the analysis that follows will be similar for unstable and stable firms: in a first step we shall deduce an expression for $a_c(q)$ using $a_c^{min}(q)$ and $\pi_m(q)$; meanwhile in a second step we shall deduce an expression for $s^{\max}$. Having done this for both unstable and stable firms, we shall then summarise the findings in a single result.

3.3.1 Unstable firms

Given an amount of assets a_j define π_c^H to be the profit of a firm who (i) invests in the risky asset earning $R^H(a_j)$ when the project is successful and (ii) pays depositors and investors $r^H(a_j)$ per unit of asset held when the project is successful. It follows that:

$$\pi_c^H(a_j) = p\Big[R^H(a_j) - a_j r^H(a)_j)\Big]$$

Note that one of the initial parameter restrictions ensures that $\pi_c^H(a_j) \to \infty$ as $a_j \to \infty$. This means that - regardless of the value of q - it is always possible to find an amount of assets a_j such that $\pi_c^H(a_j) > \pi_m(q)$. This means we can define $a_c^H(q)$ to be either (i) the amount such that when $a_j = a_c^H(q)$ then $\pi_c^H(a_j) = \pi_m(q)$ or (ii) the minimum amount $a_c^{min}(q)$ (whichever is greater). Hence:

$$a_c^H(q) = \max\Bigg\{a_c^{min}(q), \min\Big\{a_j | \pi_c^H(a_j) \geq \pi_m(q)\Big\}\Bigg\}$$

Recall that when unstable firms are acting competitively and setting $s_j = s^{\max}$, then expected marginal revenue from additional investment must equal expected marginal payment to depositors and investors. This means that:

$$pr^H\left(a_c^H(q)\right) = p(1-q)s^{max} + qc_0$$

Using the fact that $s_c^H(q) = s^{\max}$ and rearranging the inequality above leads to the following:

$$s_c^H(q) = \frac{1}{1-q}\left[r^H\left(a_c^H(q)\right) - qc_0/p\right]$$

We have now derived expressions for (i) total assets of unstable competitive firms $a_c^H(q)$ and (ii) deposit rate set by unstable competitive firms $s_c^H(q)$. The next part of our analysis examines stable competitive firms.

3.3.2 Stable firms

We first define the profits of a firm j given that (i) $(1-q)s_j + qc_0 = r^*(a_j)$:

$$\pi_c^*(a_j) = R^*(a_j) - a_j r^*(a_j)$$

We define $a_c^*(q)$ in an analogous way to the way we defined $a_c^H(q)$. In particular $a_c^*(q)$ represents either (i) the lowest value of a_j that ensures $\pi_c^*(a_j) = \pi_m(q)$ or (ii) $a_c^{min}(q)$ (whichever is greater). Therefore:

$$a_c^*(q) = \max\left\{a_c^{min}(q), \min\left\{a_j|\pi_c^*(a_j) \geq \pi_m(q)\right\}\right\}$$

Recall that when unstable firms are acting competitively and setting $s_j = s^{\max}$, then expected marginal revenue from additional investment must equal expected marginal payment to depositors and investors. This means that:

$$r^*\left(a_c^*(q)\right) = (1-q)s^{max} + qc_0$$

Using the fact that $s_c^*(q) = s^{\max}$ and rearranging the inequality above leads to the following:

$$s_c^*(q) = \frac{1}{1-q}\left[r^H\left(a_c^*(q)\right) - qc_0\right]$$

We have now derived expressions for (i) total assets of unstable competitive firms $a_c^*(q)$ and (ii) deposit rate set by unstable competitive firms $s_c^*(q)$. We now draw this preliminary analysis together in order to characterise the behaviour of competitive firms.

3.3.3 Capital ratio threshold

Define q_c^* as follows:

$$q_c^* = \min_{q>0}\left\{s_c^*(q) > s_c^H(q)\right\}$$

Recall the market clearing condition that ensures the demand for active depositors matches the supply of active depositors:

$$\gamma_c\Big[(1-q)a_c - d_0\Big] = \frac{\mu d_0}{1-\mu}$$

Rearranging this market clearing condition - and using the fact that competitive firms follow a risky strategy whenever $q < q_c^*$ - leads to the following expression for the proportion of firms following the competitive strategy $\gamma_c(q)$:

$$\gamma_c(q) = \begin{cases} \frac{\mu d_0}{(1-\mu)a_c^H(q)-d_0} & \text{if} \quad q < q_c^* \\ \frac{\mu d_0}{(1-\mu)a_c^*(q)-d_0} & \text{if} \quad q \geq q_c^* \end{cases}$$

We now bring the different parts competitive firm analysis together and state the following result:

Proposition 3.4 *Suppose the regulator chooses $q < \overline{q}$. Then:*

1. *A proportion $\gamma_c(q)$ of firms will choose to set a deposit rate $s_j > s_0$*
2. *If $q < q_c^*$ then every firm setting a deposit rate $s_j > s_0$:*
   (a) *Sets the same deposit rate $s_j = s_c^H(q) = s^{\max}$*
   (b) *Raises total assets $a_j = a_c^H(q)$*
   (c) *Invests $\theta_j = a_j$ into the risky asset*
   (d) *Remains solvent with probability p*
3. *If $q \geq q_c^*$ firm then every firm setting a deposit rate $s_j > s_0$:*
   (a) *Sets the same deposit rate $s_j = s_c^*(q) = s^{\max}$*
   (b) *Raises total assets $a_j = a_c^*(q)$*
   (c) *Invests $\theta_j = 0$ into the risky asset*
   (d) *Remains solvent with probability* 1

This mirrors the result for monopolists with the added complication that the deposit rate and size of asset base are endogenously determined. Before turning to the decision of the regulator we first investigate the relative size of the three critical thresholds namely q_m^*, q_c^* and $\overline{q}$.

3.4 Welfare

Welfare has three components namely (i) consumer surplus (CS), (ii) total firm profits (TP) and (iii) expected amount paid out through deposit insurance when firms become insolvent (DI). In particular welfare W is equal to the sum of these three components and hence:

$$\text{Welfare} \;=\; \text{Consumer Surplus} \;+\; \text{Firm Profits} \;-\; \text{Deposit Insurance}$$

We now discuss the impact of an increase in capital requirements on each of these components of welfare. We then turn to the regulators choice of capital ratio q.

3.4.1 Consumer surplus

First we state a result concerning consumer surplus:

Proposition 3.5 *Suppose the regulator increases the capital ratio from q_L to q_H where $q_L < q_H < \overline{q}$. Then:*

1. *The top deposit rate $s^{\max}$ offered by any firm decreases*
2. *If $\gamma_c(q_L) < 1$, then the proportion of firms γ_c offering the top deposit rate increases*

This result shows that increasing capital requirement has an ambiguous effect on consumer surplus. On the one hand, firms who are already acting competitively pass through the extra cost of capital requirements onto consumers thereby reducing consumer surplus. On the other hand, increasing capital requirements encourages firms who are setting a low deposit rate to behave more competitively and offer their consumers a higher deposit rate.

3.4.2 Firm profits

Secondly we state a result concerning firm profits:

Proposition 3.6 *Suppose the regulator increases the capital ratio from q_L to q_H where $q_L < q_H < \overline{q}$. Then:*

1. *If $\gamma_c(q_L) < 1$, then the profit level π_j of every firm decreases*
2. *If $\gamma_c(q_L) = 1$ and $q^*c \notin [q_L, q_H]$, then the profit level π_j of every firm remains unchanged*

This result shows increasing capital requirements decreases the profits of firms. Increasing capital requirements directly impacts the profits of monopolists, since these firms always set a deposit rate $s_j = s_0$ and so do not pass on any of the extra cost of capital requirements onto depositors. Meanwhile capital requirements indirectly impacts the profits of competitive firms by incentivising firms to set a higher deposit rate $s_j = s^{\max}$ which in turn intensifies the competition for active consumers. On the other hand, increasing capital requirements encourages firms who are setting a low deposit rate to behave more competitively and offer their consumers a higher deposit rate. [13]

3.4.3 Deposit insurance

Finally we turn to the final component of welfare, namely the cost of deposit insurance. Let γ^H be proportion of firms at risk of insolvency:

[13] The only case when increasing capital requirements does not reduce profits is when all firms are already acting competitively (with $\gamma_c = 1$). In this case, the additional cost of capital requirements is fully passed on to consumers and the profit level of firms remain unchanged.

Proposition 3.7 *Suppose the regulator increases the capital ratio from* q_L *to* q_H *where* $q_L < q_H < \overline{q}$. *Then:*

1. *If* $q_H < \min\{q_m^*, q_c^*\}$, *then* γ^H *remains unchanged* ($\gamma^H = 1$)
2. *If* $q_L > \max\{q_m^*, q_c^*\}$, *then* γ^H *remains unchanged* ($\gamma^H = 0$)
3. *If* $q_m^* < q_L < q_H < q_c^*$, *then* γ^H *increases*
4. *If* $q_c^* < q_L < q_H < q_m^*$, *then* γ^H *decreases*

This is one of the key results - namely that an increase in capital requirements can increase the proportion of firms at risk of becoming insolvent and hence also the cost of insolvency. The reason for this is that (i) an increase in capital requirements increase incentives to behave more competitively and (ii) increased competitive behaviour can increase incentives to take risks: in particular this is the case when $q_m^* < q_c^*$ and $q \in (q_m^*, q_c^*)$.

3.5 Capital ratio

Bearing in mind that increasing capital requirements actually increases the proportion of firms taking risks when (i) $q_m^* < q_c^*$ and (ii) $q \in (q_m^*, q_c^*)$ we can deduce that:

Corollary 3.8 *If* $q_m^* < q_c^*$, *then the capital ratio for the regulator to choose is either (i)* $q = 0$, *(ii)* $q = q_m^*$ *or (iii)* $q = q_c^*$.

This corollary follows from three observations. First - as discussed above - it is not optimal to set an intermediate capital ratio $q \in (q_m^*, q_c^*)$ since this increases risk taking. Secondly it is not optimal to set a capital ratio $q < (0, q_m^*)$ because such a choice is dominated by setting a capital ratio $q = 0$. This is because all firms choose the risky investment option whenever $q < q_m^*$: in this case additional capital does not improve investment decisions but diverts capital away from outside projects with better returns Thirdly it is not optimal to set a capital ratio $q > q_c^*$ because such a choice is dominated by setting a capital ratio $q = q_c^*$. This is because all firms choose the safe investment option whenever $q \geq q_c^*$: again additional capital does not improve investment decisions but diverts capital away from outside projects with better returns.

This corollary only partly characterises the regulators decision, since it does not cover the case where $q_c^* < q_m^*$. In this case we can only state a weaker version:

Corollary 3.9 *If* $q_c^* < q_m^*$, *then the capital ratio for the regulator to choose is either (i)* $q = 0$ *or (ii)* $q \in [q_m^*, q_c^*]$.

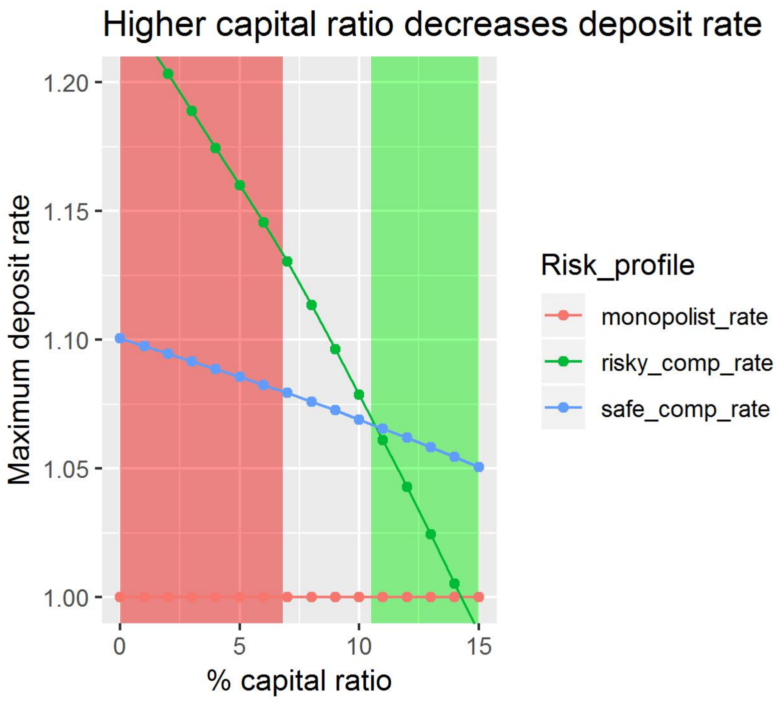
We can deduce that it is not optimal for the regulator to set a capital ratio $q \in (0, q_m^*)$ or $q > q_c^*$ by following similar reasoning to that outlined above (namely that such a choice diverts capital away from outside projects without providing any benefit). In order to obtain demonstrate these results, in tht next section we investigate a particular set of parameter values.

4 A numerical example

In this section we investigate the critical values of capital requirements for a specific case. The core example has the following parameter values:

Parameter	Baseline
s_0	1
c_0	1.4
$R_0(\theta)$	$1.1\theta + 0.1\log(1+\theta)$
$R_H(\theta)$	$1.2\theta + 0.3\log(1+\theta)$
$R_L(\theta)$	$0\theta + 0.1\log(1+\theta)$
p	0.5
d_0	1
μ	0.2

The graph below shows the implications for deposit rates depending on the regulators choice of capital ratio (q between 0% and 15%):



In this example the capital ratio threshold at which monopolist banks switch from investing in the risky asset to investing in the safe asset is equal to $q_m^* = 6.8\%$. Hence a capital ratio threshold of 6.8% will ensure that all monopolistic firms will invest in the safe asset. If there are few consumers that are active, then this will be the capital ratio threshold.

At a capital ratio level of 6.8% competitive banks prefer to choose the higher deposit rate (hence the risky strategy). Competitive banks will only adopt a deposit rate consistent with safe investments if the capital ratio is 10.5% or above. Hence, to ensure that all banks opt for a safe strategy, the capital ratio requirement needs to be significantly above

6.8%. If there are a significant percentage of customers that are active, then the choice of capital ratio is driven to a large extent by the competitive banks behaviour. If the capital ratio is below 10.5% then in this example there is limited benefit in setting a capital ratio above 0 since it has no impact on the risk choices of competitive banks. Higher capital requirements in this region are expensive, have no effect on the risk choices of competitive banks and encourage more monopolistic banks to opt for the competitive sector. Hence, the regulator would choose a zero capital requirement.

Formally, by applying the results in the previous section we can deduce that the regulator will choose a capital ratio equal either to $q \in \{0\%, 6.8\%, 10.5\%\}$. Thus, where there are significant numbers of active investors the example has the feature that the capital ratio requirement will either be high or zero depending on the other parameter values. Furthermore, we can conclude that increasing the capital ratio from q_L to q_H will increase aggregate risk-taking whenever $6.8\% < q_L < q_H < 10.5\%$.[14] This provides a numerical example of our result that there are regions where increasing minimum capital requirements will increase rather than decrease overall risk in the banking system.

5 Conclusions and Policy Implications

We have provided a model where some consumers can observe and act on all deposit rates in the market and others cannot. Open banking provides a practical motivation for such a model. New technologies (typically using application programming interfaces to allow banks and other intermediaries to access other banks customers credit histories and then to offer preferable products) are being imposed, in various forms, on the banking sector in many countries. The objective of the policy is to increase competition in the sector and hence the efficiency of the banking system and welfare.

In the presence of open banking, as modelled in the paper, banks face a choice of offering low deposit rates and taking advantage of their monopoly footprint (the monopolistic sector) or taking advantage of the new technology, that brings more customers but only at the price of higher deposit rates (the competitive sector). We show that equilibrium exists with both types of banks in the market.

Minimum capital requirements, set by regulators, have the effect of (weakly) reducing risk taking in both the monopolist and competitive sectors, as is already well documented in the literature. However, increasing capital requirements, when there are diverse business models, also impacts on the attractiveness of the different sectors. Loosely, higher capital requirements impact far more on monopolistic banks (who are already extracting rents

[14]The only possible exception is the case where $q_c^* \in [q_L, q_H]$. In this situation firms change their risk profile (moving from the risky to the safe strategy) which may increase or decrease their profits depending on parameter choices.

from their customers) than competitive bank since in the competitive sector the impact of capital requirements are passed on through the competitive process (the importance of the pass-through effect has been identified, in a slightly different context, by Repullo (2004). The net effect is that the competitive sector becomes, at the margin, more attractive than the monopolistic sector and some banks move to the competitive sector. The competitive sector sets higher deposit rates than the monopolistic sector so is more likely to adopt risky investments. Hence, raising capital requirements moves some banks into the competitive sector, which is more risky. In terms of aggregate risk, this works in the opposite direction to the conventional effect of capital requirements on risk. This has a series of implications.

One concerns the relationship between capital requirements and aggregate risk taking. This effect is reminiscent of gambling effect found in Hellman *et al.* (2000), in the sense that it identifies another counterproductive transmission channel. However our transmission channel is static in nature, so that 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 requirement impacting on the franchise value, and hence a change in current capital requirement that is temporary would have no impact on charter value, as long as the regulator could indeed credibly commit to the change being temporary. In contrast, since our transmission mechanism arises through a static framework, a higher capital requirement today could lead to greater risk in the system today.

Second, since capital requirements are passed-through in the competitive sector (hence the risk reducing properties of capital requirements are weak in this sector) and higher capital requirements make the competitive market more attractive for banks, then capital requirements need to be very high if they are to reduce risk taking by the competitive firms. On the other hand, very high capital requirements are expensive and hence unattractive. So, it may be that the social cost of achieving low risk is deemed too high. In this case the capital requirements are likely to be low since moderate increases in capital requirement raise costs to banks but achieve little in the way of risk reduction. Hence, depending on parameter values, the capital requirements could be either very high or very low.

In the light of this, an interesting reinterpretation of the model might be to imagine, alongside our existing model, a group of larger, well established banks with a stronger monopoly footprint. These banks would be less attracted to the competitive sector since they would be sacrificing a larger monopoly footprint to access the benefits of the competitive sector. In such an interpretation, our model could be seen providing insight into the question of where the capital requirements for the smaller, possibly new entrant, banks would sit as a result of open banking, and indeed other fintech solutions, providing some of them with new competitive options to capture scale. Given sufficient active customers (i.e., once the new technological solutions begin to bite), the capital requirements for the sector of smaller, less established banks may be different from the traditional banks. But this can either be far higher or far smaller, depending on parameters. This has implications for future changes in capital requirements, if open banking has sufficient impact, which we briefly consider.

There are various initiatives that impact on capital requirement differences between big and small firms. One concerns the Basel III arrangements. The Basel approach sets risk weights for banks in two different ways. If the bank has a certified Internal Ratings-Based (IRB) model then the risk weights that the bank must use are given by the banks model for those assets. If a bank does not have an IRB model, for the relevant asset class, then there is a standard approach (SA) which indicates the risk weights that must be applied. Around the world it is primarily the big banks that have IRB models (they are expensive to set up, require a history of risk management, history of data relevant to calculate loss given default, etc.) and the smaller, newer banks use the SA risk weights. Typically, the IRB risk weights are much lower than SA risk weights. For example, in 2015 the median risk weights across IRB/SA portfolios of EU banks were 15.5% for IRB compared to 42.3% for SA for mortgage exposures. The corresponding figures for retail exposures were 27% (IRB) compared to 71.6% (SA) and for corporate exposures 51.8% (IRB) compared to 94.9% (SA). Thus SA banks have far higher risk weights than IRB approved banks. The discrepancy has been the source of considerable discussion and in 2018 the Bank of International Settlements announced a series of reforms which include changes to IRB and SA approaches that will reduce the difference in risk weights once fully implemented. However, if open banking is successful it may be the case that aligning the risk weights of smaller, newer entrants with those currently applied to the traditional larger players may not be what is needed. Our analysis suggests that, while there is no unique answer as to whether the capital requirements of the less established, smaller banks should be much higher or far lower, there is an argument that the policy of trying to reduce the disparity in capital requirements may not be well founded.

There are also initiatives in place in the United States to simplify the regime for smaller banks. In November 2018 the OCC, FED and FDIC jointly proposed (based on the Economic Growth, Regulatory Relief and Consumer Protection Act of 2018) to simplify capital requirements for qualifying banks with total consolidated assets that are less than $10bn. Essentially, the proposal is that such a bank would not be required to calculate the existing risk-based requirements and leverage capital requirements as long as it had a bank leverage ratio of 9%. Our model suggests that there may be arguments for such an approach being implemented to entrants if open banking were successful in encouraging significant numbers of small, competitive, new entrants, but that one may then be looking for potentially quite high leverage ratios. However, an alternative scenario is that the social cost of such leverage ratios may be too high and that very low leverage ratios and capital requirements may be appropriate. This raises the open question of whether there are other instruments that could be used in such a scenario.

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