Imperfect Banking Competition and Financial Stability

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Abstract

Does bank competition jeopardize financial stability? By building a model of imperfect banking competition featuring the accumulation of bank equity via retained earnings, this paper finds that bank competition can have different short-run and long-run effects on financial stability. In the short run, less competition can jeopardize stability as it increases banks' loan assets and thus lowers their equity-to-assets ratios (equity ratios), making them more likely to default. In the long run, less competition tends to enhance stability as banks make higher profits and accumulate equity faster over time, resulting in higher equity ratios and hence lower bank default probabilities. The extent of this long-run stability gain from less competition and whether the stability gain outweighs the efficiency loss crucially depend on banks' dividend distribution or macroprudential policies. Empirically, this paper finds two sets of supporting evidence for the model predictions using bank-level data from EU and OECD countries. First, bank concentration, an inverse measure for competition, has a significant positive effect on the change in bank equity. Second, banks' equity ratios are found to be negatively related to their default probabilities, which are proxied by credit default swap spreads.

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1 Introduction

Does banking competition jeopardize financial stability? Understanding how banking competition affects financial stability provides crucial guidance on choosing the most effective macroprudential policy tools. Despite its importance, the relationship between banking competition and financial stability remains highly debated in the literature.

Much of the literature has focused on how bank competition affects banks' or borrowers' risk-taking.[1] Instead, this paper examines how competition affects banks' equity-to-assets ratios (equity ratios) and thereby financial stability measured through banks' default probabilities. By building a model of imperfect banking competition featuring the accumulation of bank equity via retained earnings, this paper finds that less banking competition can lead to a large gain in financial stability provided that banks retain the greater profits to build up their capital buffer.

Although less banking competition improves financial stability, it reduces aggregate output and hence macroeconomic efficiency, because a higher loan rate leads to a lower demand for physical capital and thus lower output. This paper quantifies the importance of the financial stability gain from less banking competition relative to the macroeconomic efficiency loss.

This paper shows that bank equity accumulation is important for understanding the trade-off between financial stability and macroeconomic efficiency. In the absence of bank equity accumulation, the financial stability gain from less banking competition is very small and is always outweighed by the macroeconomic efficiency loss. As a result, perfect banking competition is the best in this case. However, when banks retain their profits to build up their capital buffer over time, the financial stability gain from less banking competition can be large enough to outweigh the macroeconomic efficiency loss.

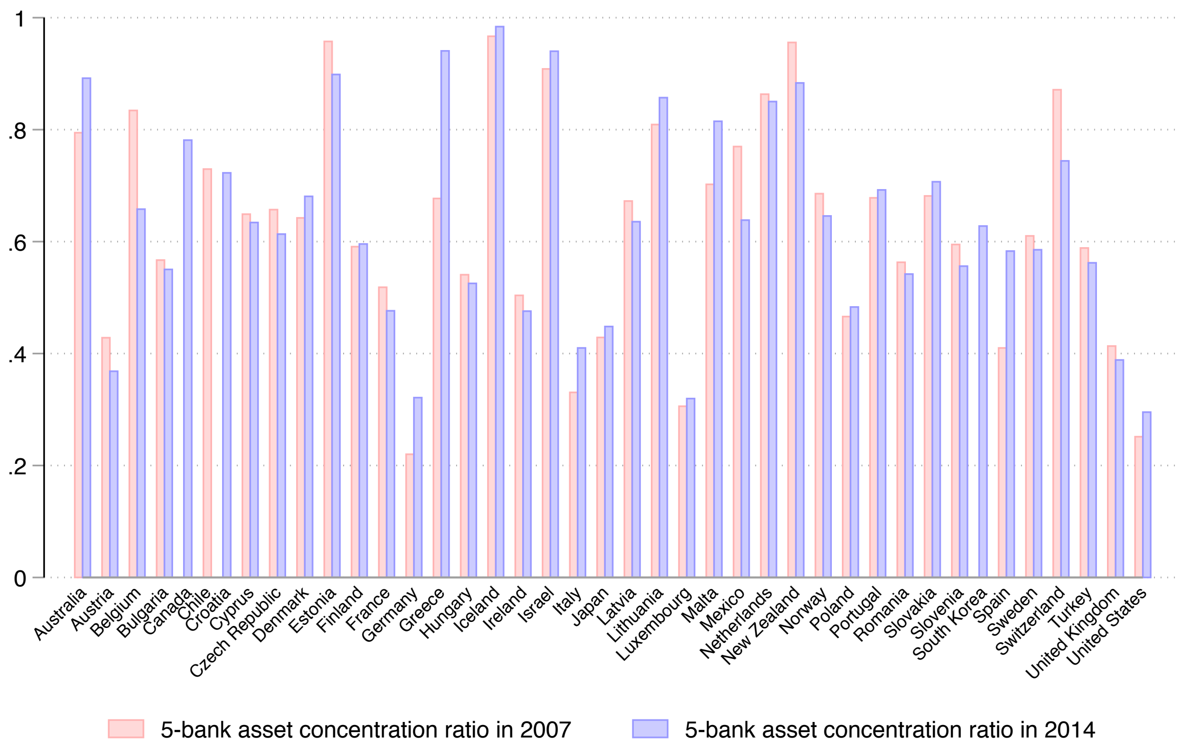
The importance of bank equity accumulation implies the relevance of macroprudential regulation on banks' dividend distribution.[2] For instance, by limiting banks' dividend distribution to shareholders, macroprudential policies can help to obtain a larger financial stability gain from less banking competition. Empirically, this paper finds supporting evidence for the model's prediction that when banks accumulate equity over time, less banking competition can lead to a large gain in financial stability measured by banks' default probabilities.

The imperfectly competitive nature of the banking sector can be seen in Figure 1, which shows that the largest 5 banks by total assets share more than 60% of the market in many EU and OECD countries in 2007 and 2014. This paper models imperfect banking competition

[1] See Corbae and Levine (2018), Boyd and De Nicolo (2005), Allen and Gale (2000), Keeley (1990), etc.

[2] Macroprudential policies can regulate banks' dividend distribution. For example, in the US, banks that fail the stress test face restrictions on dividend distribution to shareholders.

Figure 1: Bank Concentration for EU and OECD Countries in 2007 and 2014



Note: The annual country-level 5-bank asset concentration ratio is the sum of market shares of the largest 5 banks by total assets. For EU countries, this is based on credit institutions (defined as receiving deposits or other repayable funds from the public and granting credits for its own account) authorized by a given country, using ECB data. For non-EU OECD countries (i.e., Australia, Canada, Chile, Iceland, Israel, Japan, Mexico, New Zealand, Norway, South Korea, Switzerland, Turkey and US), the 5-bank asset concentration ratio is computed using Bankscope annual data.
Data sources: ECB Macroprudential Database, Bankscope

via a Cournot banking sector where banks with different efficiencies compete for loans in each period. Loans are financed by deposits and equity accumulated via retained earnings. Entrepreneurs with limited liability and no initial wealth borrow via non-state-contingent debt contracts from the banking sector, to finance the purchase of physical capital for production. Entrepreneurs face idiosyncratic and aggregate shocks to productivity after installing the physical capital. Banks can perfectly diversify the idiosyncratic risk, but cannot diversify the aggregate risk, so they can default ex post if an adverse aggregate productivity shock causes too many entrepreneurs to default and their equity is not enough to absorb the loan losses. Hence, banks with higher equity ratios are better able to withstand aggregate shocks and have lower default probabilities. This paper analyzes how banking competition affects banks' equity ratios and thereby their default probabilities.

A key theoretical insight is that less banking competition can lead to a large gain in financial stability provided that banks retain the greater profits to build up their equity over time. With less banking competition, banks have higher profit margins, which provide a buffer against losses. However, this static margin effect only has a small impact on financial stability. When taking into account that banks can accumulate the greater profits over time, less banking competition can lead to a much larger gain in financial stability. This implies an important role for macroprudential regulation on banks' dividend distribution.

The model gives rise to some empirical implications that I assess using data for EU and OECD countries from 1999 to 2016. The model predicts that when banks retain their profits as equity over time, less banking competition improves financial stability measured through banks' default probabilities. I assess this prediction in two steps. First, based on the model, less banking competition leads to a larger change in bank equity when banks retain their profits. Second, banks with higher equity ratios have lower default probabilities. I provide two sets of supporting evidence. First, bank concentration, which is used as an inverse proxy for banking competition, has a significant positive effect on the change in bank equity. Second, banks' equity ratios are negatively related to their default probabilities, proxied by credit default swap (CDS) spreads.[3] I also assess the model prediction in one step by looking at the direct relationship between banks' CDS spreads and bank concentration. I find that higher bank concentration leads to lower CDS spreads during the post-crisis period, which is consistent with the model prediction.[4]

The existing theoretical literature on the relationship between banking competition and financial stability can be classified into three categories: the competition-fragility view, competition-stability view, and an ambiguous relationship. The literature supporting the competition-fragility view tends to focus on the risk-taking channel (e.g., Corbae and Levine, 2018; Corbae and D'Erasmo, 2011; Allen and Gale, 2000; Hellmann, Murdock and Stiglitz, 2000; Matutes and Vives, 2000; Keeley, 1990) – competition reduces banks' franchise values (i.e., net present value of expected future profits) and thus induces more risk-taking by banks.[5] In contrast, there is also literature supporting the competition-stability view. For

[3]The CDS spread is the price of insurance against the default of a bank, so a higher CDS spread implies a higher bank default probability.

[4]When directly regressing banks' CDS spreads on bank concentration, the latter is only significant during the post-crisis period due to the lack of cross-country variation in CDS spreads during the pre-crisis period.

[5]Besides, bank competition can also jeopardize stability by worsening the coordination problem between depositors that can foster bank runs (Vives, 2016). Banks with long-term assets financed by short-term liabilities are vulnerable to runs, irrespective of competition, as in Diamond and Dybvig (1983). However, more intense competition raises the probability of failure in a symmetric interior equilibrium where banks are direct competitors for deposits (Matutes and Vives, 1996). Similarly, Egan, Hortaçsu and Matvos (2017) find that banks with high default probabilities are willing to offer high insured deposit rates. To compete for deposits, rival banks also raise their rates which reduce their margins and increase their default probabilities.

instance, by focusing on borrowers' risk-taking rather than banks' risk-taking, Boyd and De Nicolo (2005) introduce the risk-shifting hypothesis – competition lowers the loan rate and reduces borrowers' risk-taking, thus making banks' loan portfolio safer. Martinez-Miera and Repullo (2010) combine the risk-shifting effect with the margin effect that reduces profits and thereby the buffer against losses, and argue that the relationship between competition and stability is ambiguous, depending on which effect dominates.[6]

Similarly, the existing empirical evidence can also be classified according to three different views on the relationship between competition and stability: the competition-fragility view (e.g., Carlson, Correia and Luck, 2018; Corbae and Levine, 2018; Jiang, Levine and Lin, 2017; Beck, De Jonghe and Schepens, 2013; Ariss, 2010; Yeyati and Micco, 2007; Salas and Saurina, 2003; Keeley, 1990), the competition-stability view (e.g., Anginer, Demirgüç-Kunt and Zhu, 2014; Dick and Lehnert, 2010; Uhde and Heimeshoff, 2009; Schaeck and Cihák, 2007), and an ambiguous relationship (e.g., Faia, Laffitte and Ottaviano, 2018; Jiménez, Lopez and Saurina, 2013; Tabak, Fazio and Cajueiro, 2012). One reason to explain the mixed empirical results is that competition affects different types of risks differently, as pointed out by Freixas and Ma (2015).[7] In addition, the diversity of measures used for competition explains part of the mixed empirical results. In fact, there are papers that find that different measures for competition can lead to opposite results for the impact of competition on stability (e.g., Fu, Lin and Molyneux, 2014; Schaeck, Cihák and Wolfe, 2009; Beck, Demirgüç-Kunt and Levine, 2006).

This paper contributes to the existing literature in three major respects. First, this paper introduces a new mechanism, the equity ratio effect, whereby competition affects banks' equity ratios and thereby their default probabilities. A few papers studying bank competition and financial stability also model bank equity but they look at the role of equity in deterring bank risk-taking (Corbae and Levine, 2018; Hellmann, Murdock and Stiglitz, 2000; Keeley, 1990), or making banks commit to monitoring (Allen, Carletti and Marquez, 2011). Instead, this paper focuses on the role of equity as a buffer against loan losses. More specifically, it incorporates the static margin effect and introduces dynamic bank equity accumulation via retained earnings. Based on the calibrated model, the static

This paper does not look at how competition affects stability via the bank-run channel by assuming full deposit insurance and a perfectly elastic supply of deposits.

[6]Caminal and Matutes (2002) also find that the relationship between bank competition and banking failures is ambiguous. In their model set-up, higher borrowers' investment implies a higher failure rate of the bank and under less banking competition, both the loan rate and the monitoring effort are higher, which affect borrowers' investment differently. While a higher loan rate reduces the investment, a higher monitoring effort raises the investment.

[7]For instance, Berger, Klapper and Turk-Ariss (2009) find that banks with more market power have higher non-performing loans ratios, but have less overall risk measured by the Z-index, using more than 8000 banks in 23 developed countries from 1999 to 2005.

margin effect only has a small impact on financial stability. However, when banks retain the greater profits to build up their capital buffer, less banking competition can lead to a much larger gain in financial stability. In essence, the improved profitability of banks under less banking competition is amplified over time.

Interestingly, if policymakers try to reduce competition to improve financial stability, the model suggests that it could make things worse in the short run. In particular, if a solvent bank merges with a distressed bank during a crisis, the merged bank with greater market power would have a larger size of loan assets, which reduces its equity ratio and hence raises its default probability. However, this short-run equity ratio effect tends to disappear over time due to faster equity accumulation with less banking competition, which results in higher bank equity ratios over time (long-run equity ratio effect).

Second, the paper provides a new measure to quantify the trade-off between financial stability and macroeconomic efficiency, using a calibrated version of the model.[8] More specifically, when there is little competition, the macroeconomic efficiency loss is very large. For instance, with a monopoly bank, aggregate output is 40% lower compared with a perfectly competitive banking sector. This large macroeconomic efficiency loss completely outweighs the financial stability gain. But when there are more than six banks, the financial stability gain from less banking competition becomes large enough over time to outweigh the macroeconomic efficiency loss, when banks engage in equity accumulation.

Since bank equity accumulation can result in a large gain in financial stability under imperfect banking competition, this implies an important role for macroprudential regulation that limits banks' dividend distribution to shareholders. Such macroprudential regulation of banks' dividend distribution has not received much attention in the literature, compared to capital requirements and deposit rate regulation,[9] even though it has already been implemented in practice, most notably by the US Federal Reserve for banks that fail stress tests. Admati et al. (2013) point out that prohibiting banks' dividend payouts for a period of time is an efficient and quicker way to have banks build up equity. The long-run equity ratio effect in this paper suggests a greater effectiveness of this macroprudential policy tool under less competition, because banks make higher profits.

Third, this paper provides new empirical evidence by assessing the model prediction that

[8] As Allen and Gale (2004) point out, although it is hard to measure the efficiency loss from concentration, it is unwise to neglect the efficiency costs. To address the balance between competition and stability, it is important to have a framework that allows for welfare analysis at different levels of competition. While Corbae and Levine (2018) compare the efficient level of risk taking and investment chosen by a social planner in a frictionless economy with the levels chosen in a decentralized Cournot equilibrium embedded with other frictions, I focus on the efficiency loss caused by imperfect banking competition in this paper.

[9] See Repullo (2004), Hellmann, Murdock and Stiglitz (2000) and Besanko and Thakor (1992) for analysis on capital requirements and deposit rate ceilings.

in the presence of bank equity accumulation, less banking competition improves financial stability. In this paper, I use bank concentration as an inverse measure for competition based on the Cournot model and neglect that there may be a weak relationship between bank concentration and other banking competition measures empirically (e.g. Claessens and Laeven, 2004).[10] Based on the model, financial stability is measured by banks' default probabilities, so banks' CDS spreads are used to proxy for their default probabilities, with an additional benefit that this market-based measure is less likely to cause endogeneity problems, relative to the accounting-based measures, as noted by Anginer, Demirgüç-Kunt and Zhu (2014).[11] By assessing the model prediction in two steps, this paper provides supporting evidence for the mechanism behind the relationship between banking competition and financial stability via banks' equity ratios. Furthermore, this paper provides new evidence by investigating the direct relationship between banks' default probabilities and banking competition. I find that bank concentration, as an inverse proxy for banking competition, has a significantly negative effect on banks' CDS spreads during the post-crisis period.

The remainder of the paper is structured as follows. Section 2 presents the model set-up and the basic model results. Section 3 explains the model calibration. Section 4 uses the calibrated model to illustrate the long-run and short-run equity ratio effects, and to quantify the relative importance of the macroeconomic efficiency loss and the financial stability gain associated with imperfect banking competition. Section 5 documents the data sources used in this paper. Section 6 discusses the empirical specifications and reduced-form results supporting the model predictions. Section 7 concludes.

2 Model

A model of non-state-contingent debt contracts between competitive entrepreneurs and a Cournot banking sector is presented in this section. Entrepreneurs are born each period and only live for two periods. They start with no initial wealth and hence need to borrow from

[10] The competition measures such as HHI (Herfindahl-Hirschman Index) and 5-bank concentration ratios are based on the Structure-Conduct-Performance (SCP) hypothesis (Bikker, Shaffer and Spierdijk, 2012), which holds under Cournot competition. Under the SCP hypothesis, a highly concentrated banking industry tends to cause banks to behave in a non-competitive way to make higher profits, for instance, via non-competitive pricing. This structural measure (e.g., bank concentration measures) has been questioned a lot in terms of how well they capture competition (Bolt and Humphrey, 2015), which has led to the development of non-structural measures such as the Lerner index, Panzar-Ross H-statistic and Boone indicator, etc. However, each of these measures has also received criticism, as can be seen from Carbó et al. (2009), Bikker, Shaffer and Spierdijk (2012) and Schiersch and Schmidt-Ehmcke (2010), etc.

[11] Few papers in this literature use CDS data. A recent paper by Faia, Laffitte and Ottaviano (2018) only use CDS data on 15 global systematically important banks, while this paper covers 157 banks in EU and OECD countries.

banks at a fixed loan rate to purchase and install physical capital in their first period, which is used as the only input for production in their second period, at the end of which they consume the profits. Entrepreneurs with limited liability are assumed to be identical ex ante but their productivity is subject to an idiosyncratic shock and an aggregate shock in their second period. Banks with different efficiencies compete in loan quantities *à la* Cournot and all banks' loan quantities then determine the equilibrium loan rate. Entrepreneurs that suffer adverse productivity shocks may not be able to repay their loans, in which case banks would incur a collection cost or auditing cost to observe and verify their realized output, and then confiscate the output. Due to the large number of entrepreneurs that each receives a different idiosyncratic shock to productivity, banks can perfectly diversify the idiosyncratic loan risk. However, banks are all affected by the aggregate shock to productivity. Ex post, some banks may default after an adverse aggregate shock if their efficiency level or equity ratio is sufficiently low.

2.1 Entrepreneur's Problem

There is a unit mass of ex ante identical entrepreneurs indexed by $i \in [0, 1]$ with no initial wealth. Each borrows from a bank at a non-state-contingent gross loan rate $R_{b,t}$ to purchase physical capital $k_{i,t}$ in period t. Entrepreneurs take the loan rate $R_{b,t}$ set by the banking sector as given. There is a common deterministic productivity level $A > 0$ that is subject to multiplicative shocks that only realize at the beginning of period $t + 1$ after entrepreneurs have installed the capital. The idiosyncratic multiplicative shock $\omega \geqslant 0$ is i.i.d. across entrepreneurs and time, with a continuous c.d.f. $F(\omega)$ and $\mathrm{E}(\omega) = 1$. The aggregate multiplicative shock $\epsilon \geqslant 0$ has a continuous c.d.f. $\Gamma(\epsilon)$ and $\mathrm{E}(\epsilon) = 1$. Ex post, each entrepreneur i receives a different realized idiosyncratic shock $\omega_{i,t+1}$ and produces output $y_{i,t+1}$:

$$y_{i,t+1} = \omega_{i,t+1}\epsilon_{t+1}Ak_{i,t}^{\alpha} \tag{1}$$

where $\alpha \in (0, 1)$ is the output elasticity of capital. Facing the same $R_{b,t}$, each entrepreneur has the same demand for physical capital, so $k_{i,t} = k_t \ \forall i$.

If the realized idiosyncratic productivity shock at the beginning of period $t + 1$ is below a certain threshold $\bar{\omega}_{t+1}$, the entrepreneur is not able to repay the debt obligation $R_{b,t}k_t$, where $\bar{\omega}_{t+1}$ is determined by the following break-even condition:

$$\bar{\omega}_{t+1}\epsilon_{t+1}Ak_t^{\alpha} - R_{b,t}k_t \equiv 0 \quad \rightarrow \quad \bar{\omega}_{t+1} \equiv \frac{R_{b,t}k_t^{1-\alpha}}{\epsilon_{t+1}A} \tag{2}$$

As can be seen from (2), a higher $R_{b,t}$ leads to a higher entrepreneur's default threshold $\bar{\omega}_{t+1}$, keeping everything else unchanged, i.e., $\frac{\partial \bar{\omega}_{t+1}}{\partial R_{b,t}} > 0$. A higher realized aggregate productivity shock ϵ_{t+1} results in a lower default threshold $\bar{\omega}_{t+1}$, meaning that the proportion of defaulting entrepreneurs is smaller, i.e., $\frac{\partial \bar{\omega}_{t+1}}{\partial \epsilon_{t+1}} < 0$.

Both the idiosyncratic and aggregate shocks are unobserved ex ante (when entrepreneurs and banks are making their decisions). Ex post, entrepreneurs and banks can observe the realized aggregate shock ϵ_{t+1}. Each entrepreneur i can also observe the realized idiosyncratic shock $\omega_{i,t+1}$ ex post, but other agents need to incur an auditing cost or collection cost to observe it. Given the information asymmetry and a positive auditing cost, the optimal debt contract takes the form of a standard non-state-contingent debt contract (Gale and Hellwig, 1985). That is, the entrepreneur pays $R_{b,t}k_t$ when the repayment can be afforded (i.e., when $\omega_{i,t+1} \geqslant \bar{\omega}_{t+1}$). If the realized output is too low to cover the debt repayment (i.e., when $\omega_{i,t+1} < \bar{\omega}_{t+1}$), the entrepreneur declares bankrupt. Since each entrepreneur borrows from only one bank, the bank then verifies the defaulting entrepreneur's output, incurring a collection cost $\mu \in (0, 1)$ that is proportional to the realized output, and seizes the output.

A larger capital stock k_t requires higher productivity to break even due to the diminishing marginal product of capital, so it leads to a higher default threshold $\bar{\omega}_{t+1}$ and thus raises the entrepreneur's default probability $F(\bar{\omega}_{t+1})$, keeping everything else the same:

$$\frac{\partial \bar{\omega}_{t+1}}{\partial k_t} = \frac{(1-\alpha)R_{b,t}k_t^{-\alpha}}{\epsilon_{t+1}A} > 0 \tag{3}$$

The representative entrepreneur takes the gross loan rate $R_{b,t}$ as given and chooses k_t to maximize expected profits, taking into consideration the effect of k_t on the default threshold $\bar{\omega}_{t+1}$. Hence, the entrepreneur with limited liability maximizes the following expected profit with respect to k_t:

$$\mathrm{E}_t\left[\int_{\bar{\omega}_{t+1}(R_{b,t},k_t,\epsilon_{t+1})}^{\infty} \omega\epsilon_{t+1}Ak_t^{\alpha}dF(\omega) - \int_{\bar{\omega}_{t+1}(R_{b,t},k_t,\epsilon_{t+1})}^{\infty} R_{b,t}k_t dF(\omega)\right] \tag{4}$$

where the expectation operator $\mathrm{E}_t[.]$ is taken over the distribution of the aggregate shock ϵ_{t+1}, and the entrepreneur's default threshold $\bar{\omega}_{t+1}$ is a function of the gross loan rate $R_{b,t}$, physical capital k_t and the aggregate shock ϵ_{t+1} (as explained above). The optimal loan demand k_t decreases with $R_{b,t}$, as shown in Appendix A.1, so the loan demand curve is downward-sloping:

$$\frac{dk_t}{dR_{b,t}} = -\frac{k_t}{(1-\alpha)R_{b,t}} < 0 \tag{5}$$

The banking sector affects the demand for loans via the equilibrium loan rate. In addition, the loan rate may also affect the entrepreneur's default threshold. However, in this model setup, $\bar{\omega}_{t+1}$ is independent of the gross loan rate $R_{b,t}$, as proved in Appendix A.2:

$$\frac{d\bar{\omega}_{t+1}}{dR_{b,t}} = \frac{\partial\bar{\omega}_{t+1}}{\partial R_{b,t}} + \frac{\partial\bar{\omega}_{t+1}}{\partial k_t}\frac{dk_t}{dR_{b,t}} = 0 \tag{6}$$

The positive partial effect of $R_{b,t}$ on $\bar{\omega}_{t+1}$ is analogous to the argument made by Boyd and De Nicolo (2005) that an increase in loan rate caused by less loan market competition can reduce borrowers' profitability, inducing them to choose a higher riskiness attached to their portfolio, which undermines financial stability.[12] The main difference is that by separating the choice variable k_t from the riskiness measure $\bar{\omega}_{t+1}$, this model gives rise to the possibility that the adverse impact of the loan rate on borrowers' profitability is internalized by the borrowers themselves such that there is no overall impact of $R_{b,t}$ on $\bar{\omega}_{t+1}$. In essence, this is because entrepreneurs facing a higher interest rate would reduce their loan demand. As shown in (6), the positive partial effect of $R_{b,t}$ on $\bar{\omega}_{t+1}$ is exactly offset by the effect of the reduction in loan demand in response to a higher loan rate, so banks do not affect the entrepreneur's default threshold. The result that $\frac{d\bar{\omega}_{t+1}}{dR_{b,t}} = 0$ holds more generally if the entrepreneur has full liability.[13] The fact that the entrepreneur's default probability is unaffected by the loan rate in this model greatly simplifies the problem of the Cournot banking sector.

2.2 Cournot Banking Sector

There are N risk-neutral banks with different marginal costs competing in loan quantities *à la* Cournot. Banks are indexed by j, where $j = 1, 2, 3, ..., N$. When $N = 1$, the banking sector consists of a monopoly bank and when N approaches infinity, the banking sector is perfectly competitive. In equilibrium, the total loan demand k_t from the entrepreneur's problem is equal to the total loan supply which is provided by j banks, such that $k_t = \sum_j k_{j,t}$, where $k_{j,t}$ denotes the loan quantity supplied by bank j in period t.

Banks diversify to reduce idiosyncratic risk by lending to a fraction $\frac{k_{j,t}}{k_t}$ of randomly selected ex ante identical entrepreneurs. Once the idiosyncratic and aggregate shocks realize, entrepreneurs with realized values of $\omega_{i,t+1}(\epsilon_{t+1})$ above the threshold $\bar{\omega}_{t+1}(\epsilon_{t+1})$ would be able to repay the full debt obligation and each bank j gets the loan repayment $\int_{\bar{\omega}_{t+1}(\epsilon_{t+1})}^{\infty} R_{b,t}k_{j,t}dF(\omega)$ from these non-defaulting entrepreneurs. The entrepreneurs with realized values $\omega_{i,t+1}(\epsilon_{t+1})$

[12]When riskiness itself is a choice variable, as commonly seen in the literature (Martinez-Miera and Repullo, 2010; Boyd and De Nicolo, 2005), and when the expected revenue from the debt-financed project is strictly increasing in the riskiness, the only way to make profit facing a higher loan rate is to choose a higher riskiness.

[13]It is shown in Appendix A.2.1 that with full liability of the entrepreneur, the default threshold at the optimal k_t is $\bar{\omega}_{t+1} = \frac{1}{\epsilon_{t+1}}$, which is also independent of $R_{b,t}$. Compared with full liability, the entrepreneur chooses a larger k_t under limited liability, leading to a higher default probability $F(\bar{\omega}_{t+1})$.

below the threshold $\bar{\omega}_{t+1}(\epsilon_{t+1})$ will declare bankruptcy. In this case, banks verify and confiscate the output after incurring a collection cost, which is a fraction μ of the realized output. So bank j obtains $\frac{k_{j,t}}{k_t}(1-\mu)\int_0^{\bar{\omega}_{t+1}(\epsilon_{t+1})}\epsilon_{t+1}\omega A k_t^{\alpha} dF(\omega)$ from the defaulting entrepreneurs in its portfolio. Due to the large number of entrepreneurs, banks can perfectly diversify the idiosyncratic risk. The aggregate shock ϵ_{t+1} to productivity that hits all entrepreneurs, however, affects the fraction of entrepreneurs that default and thereby the fraction of nonperforming loans and banks' default probabilities. Consequently, banks with low efficiencies or low equity ratios can default ex post due to an adverse aggregate shock.

Assume bank j finances its loans $k_{j,t}$, which are the only assets on its balance sheet, via deposits and net worth (equity) $n_{j,t}$, which is accumulated through retained earnings. Assume there is a perfectly elastic supply of deposits at the exogenous gross deposit rate $R_t > 0$. Depositors are protected by a deposit guarantee from the government, who repays any depositors affected by bank default. Based on the balance sheet identity that assets equal the sum of liabilities (deposits) and equity, the amount of deposits taken by bank j is $(k_{j,t} - n_{j,t})$. Each bank j has a different time-invariant marginal intermediation cost for loans $\tau_j \in (0, 1)$, with higher τ_j indicating lower efficiency. Consequently, banks have different market shares in the Cournot equilibrium, with more efficient banks gaining higher market shares.

Let $\pi^B_{j,t+1}$ denote the net profit earned by bank j on period-t loans in period $t+1$. Assume bankers are appointed for one loan cycle, so they only care about maximizing the expected profit $\mathrm{E}_t\pi^B_{j,t+1}$ by choosing the loan quantity $k_{j,t}$.[14] Although bankers are short-lived, banks are long-lived and they can accumulate equity over time. The net profit of bank j in period $t+1$ depends on the aggregate shock ϵ_{t+1}:

$$\pi^B_{j,t+1} = \int_{\bar{\omega}_{t+1}(\epsilon_{t+1})}^{\infty} R_{b,t} k_{j,t} dF(\omega) + \frac{k_{j,t}}{k_t}(1-\mu)\int_0^{\bar{\omega}_{t+1}(\epsilon_{t+1})} \epsilon_{t+1}\omega A k_t^{\alpha} dF(\omega) \\ - R_t(k_{j,t} - n_{j,t}) - \tau_j k_{j,t} - n_{j,t} \tag{7}$$

where the first RHS term represents the revenue from performing loans and the second term equals the revenue from nonperforming loans, both for a given level of the aggregate shock. The third RHS term is the gross deposit interest payment, and $\tau_j k_{j,t}$ equals bank j's intermediation cost. The gross loan rate $R_{b,t}$ is a function of bank j's loan quantity and all the other banks' loan quantities. Under Cournot competition, each bank j chooses its

[14]Since bankers are appointed for one loan cycle, they do not consider the effect of the loan quantity choice $k_{j,t}$ on the bank's survival probability in future periods. In a dynamic Cournot model where bankers take into account the effect of $k_{j,t}$ on the bank's default probability, each bank would choose a smaller $k_{j,t}$ to reduce its default probability, resulting in a higher equilibrium loan rate and a higher profit. So under dynamic Cournot, banks can accumulate equity faster due to higher profits.

loan quantity $k_{j,t}$ to maximize its expected net profit, taking into account the impact of its loan quantity choice on $R_{b,t}$ and taking all the other banks' loan quantities as given. The equilibrium loan rate is determined by all banks' loan quantities.

Using the expression for $\bar{\omega}_{t+1}$ (2), it is shown in Appendix B.1 that the net profit (7) can be simplified to:

$$\pi^B_{j,t+1} = G(\epsilon_{t+1})R_{b,t}k_{j,t} - R_t(k_{j,t} - n_{j,t}) - \tau_j k_{j,t} - n_{j,t} \tag{8}$$

where $G(\epsilon_{t+1}) \equiv [1 - F(\bar{\omega}_{t+1}(\epsilon_{t+1}))] + \frac{1-\mu}{\bar{\omega}_{t+1}(\epsilon_{t+1})}\int_0^{\bar{\omega}_{t+1}(\epsilon)} \omega f(\omega)d\omega < 1$ can be interpreted as the fraction of the contractual gross loan revenue $R_{b,t}k_{j,t}$ that can be obtained by bank j for a given level of ϵ_{t+1}. The revenue fraction $G(\epsilon_{t+1})$ is smaller than one due to the nonperforming loans. The net profit of bank j can be negative if the realization of the aggregate shock in period $t+1$ is sufficiently low, more precisely, below a threshold $\bar{\epsilon}_{j,t+1}$. Although the aggregate shock is common to all banks, the default threshold $\bar{\epsilon}_{j,t+1}$ differs across banks due to different levels of equity $n_{j,t}$ and efficiency indicated by τ_j.[15] A higher bank's default threshold $\bar{\epsilon}_{j,t+1}$ implies a higher default probability for the bank.

2.2.1 Bank Equity Accumulation

Equity in period $t+1$, $n_{j,t+1}$, is modelled as the retained earnings of the continuing bank j, which is the sum of $n_{j,t}$ and net profit $\pi^B_{j,t+1}$ net of any dividend payments $D_{j,t+1}$:

$$n_{j,t+1} = n_{j,t} + \pi^B_{j,t+1} - D_{j,t+1} \tag{9}$$

where $\pi^B_{j,t+1}$ is given by (8). As can be seen from (9), macroprudential regulation on banks' dividend distribution can affect the equity accumulation via $D_{j,t+1}$, leading to different dynamics of equity over time and thus affecting banks' equity ratios under a given level of competition. This section shows three different bank dividend distribution or macroprudential policies: (i) no dividend distribution; (ii) distribute all positive net profits; (iii) distribute only if the equity ratio exceeds a desired or required level. The effects of these three policies on equity accumulation are shown below.

Bank j's default threshold $\bar{\epsilon}_{j,t+1}$ is determined by the condition that the pre-dividend net worth (equity) in period $t+1$ is zero, i.e., $\pi^B_{j,t+1} + n_{j,t} = 0$. If the loss made by bank j ($\pi^B_{j,t+1} < 0$) is too large to be absorbed by its capital buffer $n_{j,t}$, then bank j goes bankrupt. Hence, a larger net worth $n_{j,t}$ lowers bank j's default threshold $\bar{\epsilon}_{j,t+1}$. The

[15] In the model, banks have no debt, but the "default threshold" of a bank refers to the threshold at which it goes bankrupt and "defaults" on its liabilities (deposits).

negative relationship between banks' equity ratios and their default thresholds is established in Section 2.3.3.

Case I: No dividend distribution

Assuming banks do not distribute to shareholders (i.e., $D_{j,t+1} = 0$), equity accumulates as follows:

$$n_{j,t+1} = n_{j,t} + \pi^B_{j,t+1} \tag{10}$$

which is the sum of the equity in the previous period and the realized net profit. Conditional on a non-negative $n_{j,t+1}$ at the beginning of $t+1$, the continuing bank j will then choose loan quantity $k_{j,t+1}$ to maximize $\mathrm{E}_{t+1}\pi^B_{j,t+2}$.

Case II: Distribute all positive net profits to shareholders

Assume that whenever bank j makes a positive net profit ex post, it will distribute all the net profit to its shareholders, so the dividend payment in period $t+1$ before choosing the loan quantity $k_{j,t+1}$ is:

$$D_{j,t+1} = \max\{\pi^B_{j,t+1},\ 0\} \tag{11}$$

where $\pi^B_{j,t+1}$ is the net profit of bank j for a given realized aggregate shock ϵ_{t+1}. According to the evolution of equity (9), the post-dividend equity of bank j in period $t+1$ is then:

$$n_{j,t+1} = \min\{n_{j,t} + \pi^B_{j,t+1},\ n_{j,t}\} \tag{12}$$

When the realized net profit $\pi^B_{j,t+1}$ is negative, equity capital $n_{j,t}$ is used to absorb this loss, and no dividend is paid to shareholders. As long as $n_{j,t+1}$ is non-negative, bank j can stay in the market and choose the loan quantity $k_{j,t+1}$, financed by the post-dividend equity $n_{j,t+1}$ (12) and deposits.

Case III: Distribute if equity ratio exceeds the desired or required level

Assume banks have a desired or required equity ratio κ^* and they only pay dividend when the pre-dividend equity $n_{j,t} + \pi^B_{j,t+1}$ exceeds the desired/required level $\kappa^* k_{j,t}$.[16] When the pre-dividend equity ratio $\frac{n_{j,t}+\pi^B_{j,t+1}}{k_{j,t}}$ falls short of κ^*, banks do not pay any dividend in period $t+1$ and instead, they keep accumulating their equity. Hence, the dividend payment made

[16] One example of this desired equity ratio is the capital ratio set by regulatory authorities.

by bank j in period $t+1$ is:

$$D_{j,t+1} = \max\{n_{j,t} + \pi^B_{j,t+1} - \kappa^* k_{j,t},\ 0\} \tag{13}$$

According to the evolution of equity capital (9), bank j's equity in period $t+1$ after paying dividend (13) is then:

$$n_{j,t+1} = \min\{n_{j,t} + \pi^B_{j,t+1},\ \kappa^* k_{j,t}\} \tag{14}$$

Compared to Case II, even when the net profit $\pi^B_{j,t+1}$ is positive, if the pre-dividend equity $n_{j,t} + \pi^B_{j,t+1}$ is lower than the desired or required level as indicated by $\kappa^* k_{j,t}$, no dividend will be paid to the shareholders.

2.3 Basic Model Results

This section presents the basic model results and uses these results to show the macroeconomic efficiency loss from imperfect banking competition, the equity ratio effect, and the negative relationship between banks' equity ratios and their default thresholds.

2.3.1 Macroeconomic Efficiency Loss from Imperfect Banking Competition

Before any shocks realize, N heterogeneous banks with different levels of efficiency indicated by τ_j compete in loan quantities and the equilibrium loan rate is determined by all banks' choices of loan quantities. It is shown in Appendix B.1 that the equilibrium loan rate can be found by first taking the first-order condition of (7) with respect to $k_{j,t}$ for each bank j and then summing over all N banks' first order conditions. The equilibrium gross loan rate $R^*_{b,t}$ is:

$$R^*_{b,t} = \frac{R_t + \bar{\tau}}{\left(1 - \frac{1-\alpha}{N}\right) \mathrm{E}_t[G(\epsilon_{t+1})]} \tag{15}$$

where $G(\epsilon_{t+1}) \equiv \left[[1 - F(\bar{\omega}_{t+1}(\epsilon_{t+1}))] + \frac{1-\mu}{\bar{\omega}_{t+1}(\epsilon_{t+1})} \int_0^{\bar{\omega}_{t+1}(\epsilon_{t+1})} \omega f(\omega) d\omega\right] < 1$ denotes the fraction of $R_{b,t} k_{j,t}$ that can be obtained by bank j for a given level of aggregate shock ϵ_{t+1}, as can be seen in (8). This fraction is smaller than one due to the presence of defaulting entrepreneurs. A higher $\mathrm{E}_t[G(\epsilon_{t+1})]$ implies a smaller proportion of entrepreneurs are expected to default, which lowers $R^*_{b,t}$ due to less risk compensation. The parameter $\bar{\tau} \equiv \frac{1}{N} \sum_{j=1}^N \tau_j$ denotes the mean marginal intermediation cost across all banks. A higher $\bar{\tau}$ implies lower bank efficiency and raises $R^*_{b,t}$ due to a higher marginal cost. It can be seen from (15) that the equilibrium loan rate is larger than $R_t + \bar{\tau}$ due to the market power of banks for finite N and the presence of non-performing loans such that $\mathrm{E}_t[G(\epsilon_{t+1})]$ is smaller than one. With perfect banking competition (i.e., when N approaches infinity), the equilibrium loan rate

$R_{b,t}^{PC}$ is:

$$R_{b,t}^{PC} = \frac{R_t + \bar{\tau}}{\mathrm{E}_t[G(\epsilon_{t+1})]} \tag{16}$$

which is lower than $R_{b,t}^{*}$, but still larger than the marginal cost $R_t + \bar{\tau}$ due to the presence of non-performing loans.

The marginal intermediation costs for the N banks are randomly drawn from a given distribution which is assumed to be time-invariant.[17] If τ_j is too high relative to the distribution mean $\bar{\tau}$, then bank j is too inefficient to operate profitably. It is shown in Appendix B.2 that the following condition on τ_j is sufficient to ensure that all banks are able to make a positive expected net profit for $R_t \geqslant 1$:

$$R_t + \tau_j < \frac{R_t + \bar{\tau}}{\left(1 - \frac{1-\alpha}{N}\right)} \tag{17}$$

Note that this condition is satisfied if all banks are identical so that $\tau_j = \bar{\tau}\ \forall j$. Assume that τ_j is randomly drawn from a given time-invariant distribution for all levels of N, so changes in N do not affect the distribution mean $\bar{\tau}$.[18] All results in the rest of this section are proved under this assumption and condition (17). Some fundamental properties of the Cournot equilibrium are summarised in the following proposition which is proved in Appendix B.3.

Proposition 1: *A higher number of banks N*
(i) reduces the equilibrium loan rate $R_{b,t}^{*}$: $\frac{dR_{b,t}^{*}}{dN} = -\frac{(1-\alpha)R_{b,t}^{*}}{N(N-1+\alpha)} < 0$;
(ii) increases the equilibrium aggregate loan quantity k_t^{*}: $\frac{dk_t^{*}}{dN} = \frac{k_t^{*}}{N(N-1+\alpha)} > 0$;
(iii) improves macroeconomic efficiency measured through higher expected output $A(k_t^{*})^{\alpha}$.

As the number of banks N increases (more intense banking competition), the equilibrium loan rate is lower, which raises the demand for physical capital and thus leads to a higher equilibrium aggregate loan quantity. Let k_t^{PC} denote the aggregate physical capital or loan quantity under perfect banking competition when the loan rate is $R_{b,t}^{PC}$ (16). Proposition 1 shows that the expected output under perfect banking competition $\mathrm{E}_t(y_{t+1}^{PC}) = A\left(k_t^{PC}\right)^{\alpha}$ is higher than that under imperfect banking competition due to a lower loan rate and hence a higher demand for physical capital. In addition, less banking competition leads to a larger macroeconomic efficiency loss (or loss in expected output) compared to perfect banking competition.

[17] In simulation results shown in Section 4, τ_j is drawn from a reverse bounded Pareto distribution in order to produce an unequal distribution for equilibrium market shares with a few large banks and a lot of small banks.

[18] In essence, this assumes constant returns to scale for banks.

2.3.2 Equity Ratio Effect

This paper introduces a new mechanism, the equity ratio effect, which describes how competition affects banks' equity ratios $\frac{n_{j,t}}{k_{j,t}}$ and thereby banks' default probabilities. This mechanism differentiates between the short-run and long-run effects of banking competition on financial stability. The short-run equity ratio effect is a denominator effect via which banking competition changes the size of loan assets $k_{j,t}$, whereas the long-run equity ratio effect is a numerator effect via which banking competition affects the speed of equity accumulation and thereby the level of $n_{j,t}$ over time. This section explains the short-run and long-run equity ratio effects in turn. To analyze the former effect, it is necessary to show how bank j's loan quantity $k_{j,t}$ changes with N, while for the latter, it is important how bank j's net profit $\pi^B_{j,t}$ changes with N.

It is shown in Appendix B.4 that each bank j's optimal equilibrium loan quantity $k^*_{j,t}$ is:

$$k^*_{j,t} = \frac{1}{1-\alpha}\left[1 - \frac{(1-\frac{1-\alpha}{N})(R_t+\tau_j)}{(R_t+\bar{\tau})}\right] k^*_t = ms^*_{j,t}k^*_t \tag{18}$$

where $ms^*_{j,t} \equiv \frac{1}{1-\alpha}\left[1 - \frac{(1-\frac{1-\alpha}{N})(R_t+\tau_j)}{(R_t+\bar{\tau})}\right]$ denotes the equilibrium market share. If banks are identical, so $\tau_j = \bar{\tau}\ \forall j$, then each bank has a market share of $\frac{1}{N}$ in the Cournot equilibrium. It can be seen that the equilibrium market share depends on the marginal intermediation cost τ_j. More specifically, when bank j has a below average marginal intermediation cost (i.e., $\tau_j < \bar{\tau}$), its market share will be larger than $\frac{1}{N}$. Since $\sum_{j=1}^{N} ms_{j,t} = 1$, $ms^*_{j,t}$ must be less than or equal to one given each bank's market share is positive under the parameter restriction on τ_j (17). Using (17) and (18), the fact that $0 < ms^*_{j,t} \leqslant 1$ implies that the marginal cost for loans, $R_t + \tau_j$, must lie within the following range:

$$\frac{\alpha(R_t+\bar{\tau})}{(1-\frac{1-\alpha}{N})} \leqslant R_t + \tau_j < \frac{R_t+\bar{\tau}}{(1-\frac{1-\alpha}{N})} \tag{19}$$

Proposition 2 which is derived in Appendix B.4, shows the bank-specific marginal intermediation cost τ_j affects the extent to which a bank's market share is decreasing in N.

Proposition 2: *A higher number of banks N reduces the market share of each bank, and this effect is stronger for less efficient banks (with higher τ_j):* $\frac{dms^*_{j,t}}{dN} = -\frac{(R_t+\tau_j)}{N^2(R_t+\bar{\tau})} < 0$.

When banks have different efficiency levels, how bank j's equilibrium loan quantity $k^*_{j,t}$ changes with an increase in the number of banks N depends on the balance between the effect of an increasing aggregate loan quantity and the effect of a falling market share:

$$\frac{dk^*_{j,t}}{dN} = ms^*_{j,t}\frac{dk^*_t}{dN} + k^*_t\frac{dms^*_{j,t}}{dN} \tag{20}$$

As N increases (i.e., more intense banking competition), the aggregate loan quantity k^*_t is higher ($\frac{dk^*_t}{dN} > 0$ by Proposition 1), but each bank has a smaller share of the market ($\frac{dms^*_{j,t}}{dN} < 0$ by Proposition 2). Consequently, the sign of $\frac{dk^*_{j,t}}{dN}$ is ambiguous. If the fall in market share of bank j dominates the effect from the increase in total loan quantity, then bank j's loan quantity decreases in N. This requires banks to be identical or have sufficiently similar efficiency levels,[19] as is summarized in Proposition 3, which is proven in Appendix B.5.

Proposition 3: *When banks have sufficiently similar efficiency levels such that* $\frac{R_t+\bar{\tau}}{(2-\alpha)(1-\frac{1-\alpha}{N})} < R_t + \tau_j < \frac{R_t+\bar{\tau}}{1-\frac{1-\alpha}{N}}$*, bank j's equilibrium loan quantity $k^*_{j,t}$ unambiguously decreases with N. This condition is satisfied if all banks are identical for $N > 1$.*

Proposition 3 is important for the short-run equity ratio effect which predicts that less banking competition can jeopardize financial stability in the short run. When a reduction in N in period t increases $k_{j,t}$, it leads to a lower equity ratio $\frac{n_{j,t}}{k_{j,t}}$ as the bank's equity $n_{j,t}$ is not affected in period t. Thus, the short-run equity ratio effect operates via the denominator $k_{j,t}$.

In contrast, the long-run equity ratio effect operates via the numerator as competition affects bank's net profit and hence equity accumulated over time, as described in the following proposition, which is derived in Appendix B.6.

Proposition 4: *The expected profit of bank j decreases with the number of banks N, as the higher loan rate $R^*_{b,t}$ resulting from less banking competition dominates the changes in loan quantity $k_{j,t}$.*

According to the dynamics of bank equity accumulation (9), a higher net profit $\pi^B_{j,t+1}$ leads to a higher $n_{j,t+1}$ and a larger change in bank equity, as long as not all positive profits are distributed as dividends. Together with Proposition 4, this implies the long-run equity ratio effect – with less banking competition, banks make higher profits and can accumulate equity faster, leading to higher equity ratios and thereby lower default probabilities over time, as shown next.

[19] This condition is satisfied for the calibration in Section 3.

2.3.3 Equity Ratio Effect and Banks' Default Probabilities

In this paper, financial stability is measured through banks' default probability $\Gamma(\bar{\epsilon}_{j,t+1})$. By showing how banks' default threshold $\bar{\epsilon}_{j,t+1}$ is determined, the short-run and long-run equity ratio effects on financial stability are explained and compared with the static margin effect.

Since banks cannot diversify away the aggregate risk, an adverse aggregate productivity shock ϵ_{t+1} will cause more entrepreneurs than expected to default and as a result, banks can make negative net profits $\pi^B_{j,t+1}$. If bank j's loss is too large to be absorbed by its equity $n_{j,t}$, its pre-dividend equity $n_{j,t} + \pi^B_{j,t+1}$ will turn negative and it has to default on its liabilities. The threshold for the realized aggregate shock $\bar{\epsilon}_{j,t+1}$ below which bank j defaults is determined by the following condition:

$$\pi^B_{j,t+1}(\bar{\epsilon}_{j,t+1}) + n_{j,t} = 0 \tag{21}$$

where $\pi^B_{j,t+1}(\bar{\epsilon}_{j,t+1}) \equiv G(\bar{\epsilon}_{j,t+1}) R^*_{b,t} k^*_{j,t} - R_t(k^*_{j,t} - n_{j,t}) - \tau_j k^*_{j,t} - n_{j,t}$ represents the equilibrium net profit when the aggregate shock takes a value of $\bar{\epsilon}_{j,t+1}$, based on (8). The LHS of (21) represents the pre-dividend equity in period $t+1$. Although the aggregate shock is common to all banks, each bank j's default threshold $\bar{\epsilon}_{j,t+1}$ differs due to their specific τ_j and $n_{j,t}$. Condition (21) shows that when the realized aggregate shock takes a value of $\bar{\epsilon}_{j,t+1}$, the proportion of non-performing loans is at such a level that the negative profit for bank j is just absorbed by $n_{j,t}$. If ϵ_{t+1} is below $\bar{\epsilon}_{j,t+1}$, the pre-dividend equity will be negative and bank j will default. Dividing (21) by $k^*_{j,t}$ and substituting the definition of $\pi^B_{j,t+1}(\bar{\epsilon}_{j,t+1})$, bank j's default threshold is determined by the following condition:

$$R^*_{b,t} G(\bar{\epsilon}_{j,t+1}) - (R_t + \tau_j) + R_t \frac{n_{j,t}}{k^*_{j,t}} = 0 \tag{22}$$

where $R^*_{b,t} G(\bar{\epsilon}_{j,t+1}) - (R_t + \tau_j)$ is the bank's profit margin when the realized aggregate shock takes a value of $\bar{\epsilon}_{j,t+1}$. The bank's revenue fraction $G(\epsilon_{t+1})$ is increasing in the aggregate productivity shock ϵ_{t+1}, as fewer entrepreneurs default, so $G'(\bar{\epsilon}_{j,t+1}) > 0$ as shown in Appendix B.7. Let $\kappa_{j,t} \equiv \frac{n_{j,t}}{k^*_{j,t}}$ denote bank j's equilibrium equity ratio. Then it is straightforward to see from (22) that banks' default thresholds $\bar{\epsilon}_{j,t+1}$ and hence default probabilities are negatively correlated with their equity ratios. Intuitively, this is because with higher equity ratios, banks can still survive even with a lower realized aggregate shock. The result is summarized in the following proposition, which is formally derived in Appendix B.7:

Proposition 5: *Banks' default thresholds $\bar{\epsilon}_{j,t+1}$ are negatively related to banks' equity ratios $\kappa_{j,t}$: $\frac{d\bar{\epsilon}_{j,t+1}}{d\kappa_{j,t}} = -\frac{R_t}{R^*_{b,t} G'(\bar{\epsilon}_{j,t+1})} < 0 \ \forall j$.*

Recall that $\Gamma(\epsilon)$ denotes the c.d.f. of the aggregate shock and bank j defaults if $\epsilon_{t+1} < \bar{\epsilon}_{j,t+1}$. So a high default threshold $\bar{\epsilon}_{j,t+1}$ leads to a high default probability $\Gamma(\bar{\epsilon}_{j,t+1})$. Thus, Proposition 5 implies a negative relationship between banks' default probabilities and their equity ratios.

This paper focuses on how imperfect banking competition affects banks' equity ratio and hence their default probabilities. The role of the equity ratio effects can be shown by implicitly differentiating bank j's default condition (21) with respect to the number of banks N, as shown in Appendix B.8:

$$\frac{d\bar{\epsilon}_{j,t+1}}{dN} = \frac{\overbrace{R_t \frac{n_{j,t}}{k^*_{j,t}} \frac{dk^*_{j,t}}{dN} \frac{1}{k^*_{j,t}}}^{\text{SR equity ratio effect}} \quad \overbrace{-R_t \frac{1}{k^*_{j,t}} \frac{dn_{j,t}}{dN}}^{\text{LR equity ratio effect}} \quad \overbrace{-\frac{dR^*_{b,t}}{dN} G(\bar{\epsilon}_{j,t+1})}^{\text{margin effect}}}{R^*_{b,t} G'(\bar{\epsilon}_{j,t+1})} \tag{23}$$

Suppose that banks' efficiency levels are sufficiently similar so that $\frac{dk_{j,t}*}{dN} < 0$ by Proposition 3. According to (23), when N is lower, there is a short-run equity ratio effect that predicts a higher default probability due to a lower equity ratio, provided that the bank has equity $n_{j,t} > 0$. This is because when N is lower, each bank has greater market power and hence a larger loan quantity $k^*_{j,t}$. This reduces bank j's equity ratio $\frac{n_{j,t}}{k^*_{j,t}}$ for a given $n_{j,t}$, which leads to a higher default threshold $\bar{\epsilon}_{j,t+1}$. In addition, there is a long-run equity ratio effect such that a lower N tends to raise future equity via higher profits (by Proposition 4), which increases bank j's equity ratio in the long run and thereby reduces its future default threshold. In contrast, the static margin effect predicts that a lower N reduces the default threshold $\bar{\epsilon}_{j,t+1}$ due to a higher loan rate (as $\frac{dR^*_{b,t}}{dN} < 0$ by Proposition 1) and thus higher revenue from performing loans, which provide a buffer against loan losses.

How $\bar{\epsilon}_{j,t+1}$ changes with N in the short run (when $\frac{dn_{j,t}}{dN} = 0$) is ambiguous theoretically. For the calibration of the model described in the next section, the short-run equity ratio effect tends to dominate the static margin effect and as a result, less banking competition tends to raise banks' default probabilities and undermine financial stability in the short run. Over time, the short-run equity ratio effect tends to disappear, provided that banks retain their profits to build up equity. These results are summarized in Proposition 6, which is formally shown in Appendix B.8.

Proposition 6: *In the short run, less banking competition can jeopardize financial stability by lowering banks' equity ratios. However, when banks retain the greater profits to build up their equity over time, less banking competition can enhance financial stability.*

The extent of the financial stability gain from less banking competition over time (long-run equity ratio effect) depends on banks' dividend distribution or macroprudential policies. For instance, if banks do not distribute to shareholders and equity is accumulated over time via past profits, this can lead to a large gain in financial stability from less banking competition, which is shown in Section 4. By restricting banks' dividend payment to shareholders, macroprudential policies can thus help to ensure a larger gain in financial stability under imperfect banking competition.

The model is first calibrated in Section 3 and then simulated to illustrate three model implications. First, less banking competition can lead to a large gain in financial stability provided that banks accumulate equity over time. This shows the relevance of macroprudential regulation on banks' dividend distribution. Second, a bank merger that reduces banking competition can raise the default probability of the merged bank by lowering its equity ratio. Third, less banking competition leads to a larger macroeconomic efficiency loss and whether this efficiency loss outweighs the financial stability gain depends on the extent of equity accumulation and macroeconomic volatility.

3 Calibration

The model is calibrated to match the data for Germany during the period of 1999-2014 on nine key variables, i.e., 5-bank asset concentration ratio, HHI concentration index (Herfindahl-Hirschman Index), mean market share, corporate lending rate, interest income to total assets ratio, non-interest expense to total assets ratio, loan impairment cost ratio, equity ratio, and bank's default probability. The first four variables indicate banks' market power and concentration in the banking sector, while the remaining variables include ratios that indicate banks' leverage, profitability and cost efficiency.

The last column in Table 1 shows the mean values of the nine variables in the data for Germany. The net corporate lending rate ($R_{b,t} - 1$) is empirically constructed by averaging two country-level corporate lending rate series (i.e., for loans of up to 1 million EUR and for loans of over 1 million EUR) across years (2000-2014), where the lending rates are from the ECB. HHI is the sum of squared market shares of all banks, where the market share of a given bank in a given year $\frac{k_{j,t}}{k_t}$ is computed as the ratio of the bank's total assets to the sum of total assets of all banks in that year.[20] HHI ranges from $\frac{1}{N}$ to one and a higher value implies higher bank concentration. The 5-bank concentration ratio is the sum of the market

[20]Loans are assumed to be the only assets on banks' balance sheets in the model, so total assets are used to proxy for $k_{j,t}$ empirically.

shares of the five largest banks by total assets. Both concentration measures are obtained from the ECB and the numbers reported in Table 1 are mean values over the period of 1999-2014. The remaining variables are calculated using Bankscope annual balance sheet data for six types of banks in Germany during the period of 1999-2014.[21]

The loan impairment cost ratio in the model is $\frac{R_{b,t}k_{j,t}(1-\mathrm{E}_t[G(\epsilon_{t+1})])}{R_{b,t}k_{j,t}}$, where the numerator reflects the loss in gross loan revenue due to non-performing loans and the denominator is the gross loan revenue if all loans are repaid. Empirically, the loan impairment charge is used to proxy for the numerator and gross loans are used as the denominator since gross loan revenue is not available in data. So the loan impairment charge to gross loans ratio is used to proxy for the loan impairment cost ratio $(1-\mathrm{E}_t[G(\epsilon_{t+1})])$ in the model. The average total equity to total assets ratio $\frac{n_{j,t}}{k_{j,t}}$ across banks in Germany over 1999-2014 is around 7.2%, so the desired equity ratio κ^* is set to be 7.2%. Interest income to total assets $\frac{\pi^B_{j,t}}{k_{j,t}}$ is calculated as the gross interest and dividend income net of the total interest expense over total assets. The marginal intermediation cost τ_j in the model is empirically proxied by total non-interest expenses to total assets ratio. Bank's default probability in the model is $\Gamma(\bar{\epsilon}_{j,t+1})$, where $\Gamma(.)$ is the c.d.f. the aggregate shock distribution. The risk-neutral annual bank's default probability of 2.01% in the data is computed from the average CDS spread of 122 basis points across German banks during 2003-2014 based on Hull (2012).[22]

I calibrate the model parameters to match the value of these nine variables in the data for Germany. Table 1 compares the mean values of these variables computed using the simulated data with those in the real data. The capital share α is set at 0.3. A value of α larger than 0.5 leads to an unrealistically large gross loan rate.[23] The desired equity-to-assets ratio is set at 0.072 to match the average equity ratio of around 7.2% across banks in Germany during 1999-2014. Both the deterministic productivity level A and the exogenous gross deposit rate R is set at one. The distribution for the idiosyncratic productivity shock ω is assumed to be lognormal with the mean set to be -0.15, so that the probability of entrepreneurs' default $F(\bar{\omega}_{t+1})$ is around 3%, following the literature (e.g., Bernanke, Gertler and Gilchrist, 1999). Since the expected value of ω is one, the variance of the log-normal distribution needs to be 0.3. The distribution for the aggregate productivity shock ϵ is assumed to be lognormal with the variance chosen to be 0.28 to match the average default probability of 2.01% in data. The collection cost parameter $\mu \in [0,1]$ is set at 0.04 to match the mean loan impairment

[21] The sample of banks used consists of bank holding companies, commercial banks, cooperative banks, finance companies, real estate & mortgage banks, and savings banks.

[22] Following Egan, Hortaçsu and Matvos (2017) and Hull (2012), the probability of default is calculated under a risk neutral model with a constant hazard rate, assuming that the recovery rate is 40% and the risk-free rate or LIBOR is 3%.

[23] For example, $\alpha = 0.7$ gives R_b higher than 1.5 for N ranging from 1 to 20.

Table 1: Matching Key Variables with Data for Germany During 1999-2014

Variable	Model (N=60) Identical τ	Model (N=60) Heterogeneous τ	Data Germany
5-bank asset concentration	0.083	0.229	0.249
HHI (total assets)	0.017	0.025	0.021
Net corporate lending rate	5.07%	5.07%	4.06%
Loan impairment charge/gross loans	0.006	0.006	0.006
Non-interest expense/total assets	0.032	0.032	0.026
Bank's default probability	2.13%	2.13%	2.01%
Interest income/total assets	0.012	0.012	0.024
Mean market share	0.017	0.017	0.000
Desired total equity/total assets	0.072	0.072	0.072

Data sources: ECB, Bankscope, Thomson Reuters EIKON
Note: The numbers reported in the last column are mean values across banks and years (across years) for bank-level (country-level) variables. Data on the first three variables are from the ECB. The remaining variables except for bank's default probability are computed using Bankscope annual statements. Variables from Bankscope are winsorized at 1% of the top and the bottom of the distribution. Bank's default probability is calculated using the average CDS spread across banks from Thomson Reuters EIKON. All the numbers in the two model columns are model results, except for the desired equity to assets ratio which is calibrated.

charge to gross loans ratio of 0.006.

Banks' marginal intermediation costs τ_j are randomly drawn from a reverse bounded Pareto distribution with a support of $[0.001, 0.04]$ and a shape parameter of 0.1.[24] The distribution needs to be bounded to ensure a non-negative market share. In essence, the bounded Pareto distribution is the conditional distribution that results from restricting the domain of the Pareto distribution to $[0.001, 0.04]$. As shown in (17), τ_j cannot be larger than a certain factor of the mean $\bar{\tau}$, otherwise bank j is too inefficient to operate profitably. The bounded Pareto distribution is reversed to give a long left tail, such that most simulated banks have a τ_j close to 0.04 and only a few banks will have a relatively low τ_j close to 0.001, resulting in a market share distribution with a few large dominant banks and a lot of small inefficient banks. High bank concentration and a small mean market share across banks in the data, as can be seen in Table 1, indicate that the banking sector tends to be dominated by a few dominant players with high market shares, alongside a lot of small banks with very low market shares. The support of $[0.001, 0.04]$ is chosen to match the average non-interest

[24] Increasing the upper bound of the support will raise the mean marginal intermediation cost across banks $\bar{\tau}$ and the equilibrium loan rate. The support of $[0.001, 0.04]$ means the lowest and highest value that τ_j can take is 0.001 and 0.04 respectively. The shape parameter is the tail index and a smaller value gives a heavier tail. The Pareto distribution is a skewed and heavy-tailed distribution that allows a more dispersed distribution of bank efficiency, which gives rise to a more unequal market share distribution.

expense to total assets ratio (or $\bar{\tau}$ in the model) of 0.026. The shape parameter is chosen to be 0.1 to give a skewed distribution for market shares. More details on the distribution for τ can be found in Appendix C.1.

Together with the calibration for the aggregate shock distribution, the number of banks N is chosen to be 60 to match the concentration measures, mean market share, average corporate lending rate, and the interest income to assets ratio with empirical data. Further increasing N lowers the mean market share and brings it closer to the mean market share of almost zero in data, but at the same time, it also reduces the interest income to total assets ratio due to a lower equilibrium loan rate.

Table 1 shows that bank concentration measures computed using the simulated data based on the model with heterogeneous banks (with different τ_j) are very close to the measures in the data. In contrast, the concentration measures predicted by the model with identical banks ($\tau_j = \bar{\tau}\ \forall j$) are much lower than those in the data. This is because with $N = 60$, each identical bank only has a small market share. A summary table of the calibrated parameters is shown in Table 5 in Appendix C.2.

4 Simulation Results

Using the calibrated model, this section illustrates the long-run equity ratio effect, the short-run equity ratio effect and quantifies the relative importance of the financial stability gains and macroeconomic efficiency losses associated with imperfect banking competition.[25] Section 4.1 shows the average financial stability gain across heterogeneous banks relative to the perfect banking competition benchmark over time, for different numbers of banks N and different bank dividend distribution or macroprudential policies. In addition, it also shows the financial stability gain for banks with different market shares relative to the perfect banking competition benchmark over time under a given level of banking competition (or a given N). Section 4.2 uses a bank merger scenario to illustrate the short-run equity ratio effect. Section 4.3 quantifies the macroeconomic efficiency loss from imperfect banking competition and constructs a new measure to compare its importance relative to the financial stability gain.

[25]The model consists of a few systems of nonlinear equations, which are solved using Julia JuMP and Ipopt. More specifically, after solving for the equilibrium loan rate and the market shares, the profit of each bank is known and the equity accumulation process can be determined for each bank under different banks' dividend distribution or macroprudential policies. Given the equity dynamics of banks, their default thresholds or default probabilities in each period can be solved.

4.1 Financial Stability Gain from Imperfect Banking Competition

This section illustrates the long-run equity ratio effect, assuming all banks have the same initial equity ratio across different levels of banking competition, to focus on the effect of the number of banks N on financial stability.

In this section, the financial stability gain of bank j is measured by the difference between the default probability of the representative bank under perfect banking competition $\Gamma(\bar{\epsilon}_{t+1}^{PC})$ and bank j's default probability under imperfect banking competition $\Gamma(\bar{\epsilon}_{j,t+1})$:

$$\text{Financial Stability Gain of Bank } j = \Gamma(\bar{\epsilon}_{t+1}^{PC}) - \Gamma(\bar{\epsilon}_{j,t+1}) \tag{24}$$

where $\Gamma(\epsilon)$ is the continuous c.d.f. for the aggregate shock ϵ. Following (22), the default threshold of the representative bank $\bar{\epsilon}_{t+1}^{PC}$ is determined by:

$$R_{b,t}^{PC} G(\bar{\epsilon}_{t+1}^{PC}) - (R_t + \bar{\tau}) + R_t \frac{n_t}{k_t} = 0 \tag{25}$$

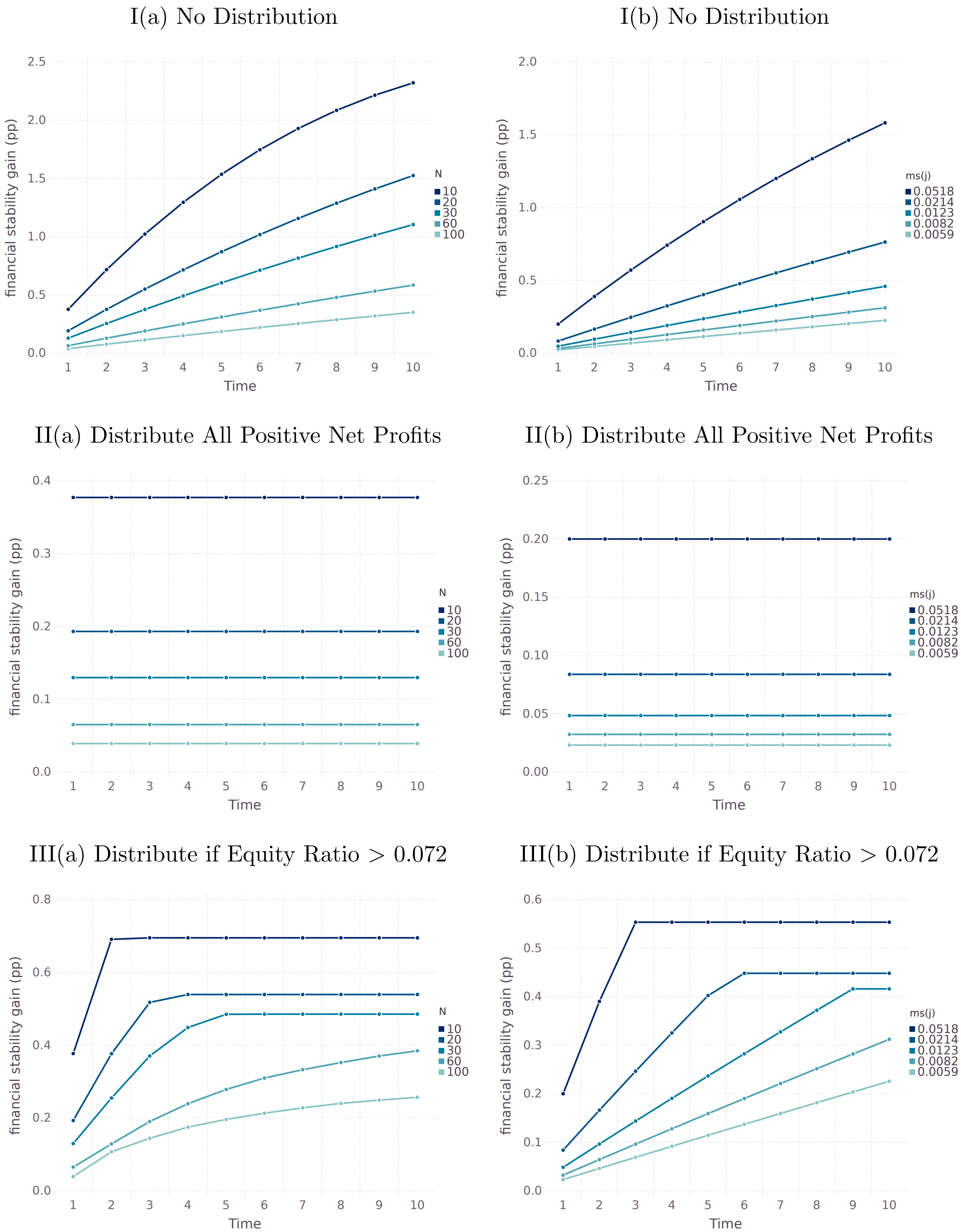
where the equilibrium gross loan rate $R_{b,t}^{PC}$ under perfect competition can be found from the equilibrium loan rate (15) by setting N to infinity. The representative bank is assumed to have a marginal intermediation cost of $\bar{\tau}$, which equals the mean marginal intermediation cost across banks under imperfect banking competition. Without aggregate shocks, the representative bank under perfect competition always makes a zero profit, so the equity ratio $\frac{n_t}{k_t}$ is equivalent to its initial level and its default threshold $\bar{\epsilon}_{t+1}^{PC}$ is constant over time. By contrast, each bank under imperfect competition has a different marginal intermediation cost and hence a different profit margin, which leads to differences in equity ratios and thus default thresholds across banks and over time.

Figure 2 plots the average financial stability gain across heterogeneous banks for different levels of competition (i.e., different number of banks N) and the financial stability gain of banks with different market shares for a given (baseline) level of N.[26] In each case, the effects on financial stability gains over time are shown for the three different bank dividend distribution or macroprudential policies presented in Section 2.2.1. For each N, banks' marginal intermediation costs τ_j are randomly drawn from the same reverse bounded Pareto distribution. To focus on the effects coming from imperfect banking competition for a fixed N, assume the realization of aggregate shocks is $\epsilon = 1$ throughout.

Graphs in the first column of Figure 2 plot the average financial stability gain (in percentage points) of heterogeneous banks under imperfect banking competition, which equals

[26] The mean financial stability gain of identical banks with the same marginal intermediation cost $\bar{\tau}$ for different N gives very similar results to the case of heterogeneous banks with different τ_j, so the former case is not shown in this section.

Figure 2: Financial Stability Gain from Imperfect Banking Competition



Note: Financial stability gain is measured by the differences in banks' default probabilities between perfect and imperfect banking competition, based on (24). Graphs in the first column plot the average stability gain (in percentage points) across heterogeneous banks with different marginal intermediation cost τ_j over time for different numbers of banks N, while graphs in the second column plot the stability gain (in percentage points) of 5 different banks at 5 percentiles (1st, 25th, 50th, 75th, 99th) of the equilibrium market share ms_j^* for $N = 60$. Each row shows a different case of bank dividend distribution or macroprudential policies.

$\frac{1}{N}\sum_j \left(\Gamma(\bar{\epsilon}_{t+1}^{PC}) - \Gamma(\bar{\epsilon}_{j,t+1})\right) * 100$, following (24). As can be seen in graph I(a) of Figure 2, the average financial stability gain across banks in period 1 is slightly higher for smaller N (i.e., less banking competition), which is purely caused by the static margin effect as banks are assumed to start with the same initial equity ratio for simplicity. But the differences in financial stability gain across different N are amplified over time due to bank equity accumulation that leads to higher equity ratios over time. By contrast, if all positive net profits are distributed away, as shown in graph II(a), bank equity accumulation is absent and hence the financial stability gain does not increase over time. The differences in the mean financial stability gain across banks for different N are only caused by the static margin effect in this case.

Graph III(a) shows the case where banks only distribute profits if their equity ratios exceed the desired or required level κ^*, which is calibrated to be 0.072 based on the average equity ratio across banks in Germany during 1999-2014. Starting with zero initial equity, for smaller values of N, banks face less competition, so they have higher profits and accumulate equity faster, resulting in lower default probabilities compared to the perfect banking competition benchmark. As a result, their financial stability gains increases more quickly during the first few periods. Once banks' equity ratios reach κ^*, (positive) profits are distributed to shareholders, so there is no further increase in financial stability gains, as shown in graph III(a).

Comparing graph I(a) without dividend distribution to graph II(a) with full distribution of positive profits shows the power of the long-run equity ratio effect. Since the financial stability gain from less banking competition is largely attributed to the accumulation of greater profits over time rather than the static margin effect, macroprudential policies that limit banks' dividend distribution can significantly increase the financial stability gains.

Graphs in the second column of Figure 2 plot the financial stability gain of banks with different market shares under a given level of competition ($N = 60$ as in the baseline calibration) over time. Banks are ranked according to their marginal intermediation costs τ_j, where banks with lower τ_j have higher equilibrium market shares. Five banks at five different percentiles (1st, 25th, 50th, 75th, 99th) of τ_j are plotted. The legend shows the corresponding equilibrium market share for each bank ms_j. As can be seen in graph I(b), when there is no dividend distribution, a more efficient larger bank has a higher financial stability gain over time due to a higher profit margin and faster equity accumulation. By contrast, when profits are distributed away, as shown in graph II(b), differences in financial stability gain between banks are purely caused by the differences in profit margins (margin effect), which are relatively small compared to the differences caused by equity accumulation. Graph III(b) shows that when banks distribute only if their equity ratios exceed κ^*, the financial stability gain of a larger bank is higher due to a larger profit margin and faster equity accumulation. Once banks' equity ratios reach κ^*, the differences in the financial stability gain across banks are purely caused by the margin effect. As shown in graph III(b), the smallest bank with a market share of 0.59% accumulates equity very slowly due to a lower profit margin and even after 10 periods, its equity ratio still has not reached κ^*.

4.2 Bank Merger Scenario

This section illustrates the short-run equity ratio effect using a bank merger scenario where solvent banks that survived a crisis merge with distressed banks that have little equity. This is an interesting case to look at since the massive public intervention and bank mergers during the 2007-2009 crisis have distorted banking competition and led to increased bank concentration in many countries (Vives, 2011).[27] Unlike an increase in the number of banks N, which is clearly due to new entrants, a reduction in N can be caused by bank exits or bank mergers. The magnitude and the direction of the short-run equity ratio effect depend on the causes for the reduction in N. In the case of bank exits, the remaining banks' equity levels are unaffected, so their equity ratios unambiguously fall after the increase in concentration. By contrast, in the case of a bank merger, the equity of the merged bank (which is the sum of the two banks' equity levels before the merger) increases. Nevertheless, when a solvent bank merges with a distressed bank with little equity, the equity of the merged bank may not increase as much relative to the increase in loan quantity due to the greater market power, resulting in a lower equity ratio.[28]

Assume there are N banks in period 0, with half being relatively more efficient with a lower marginal intermediation cost τ_j of 0.024, and the other half being less efficient with a higher marginal intermediation cost of 0.04.[29] An adverse aggregate productivity shock in period 0 wipes out the equity of those inefficient banks, so they are left with zero equity. The efficient banks are also affected by the aggregate shock but are less badly hit and have a positive equity ratio of $\kappa^* = 0.072$ in graph (a) of Figure 3. In period 1, each solvent bank

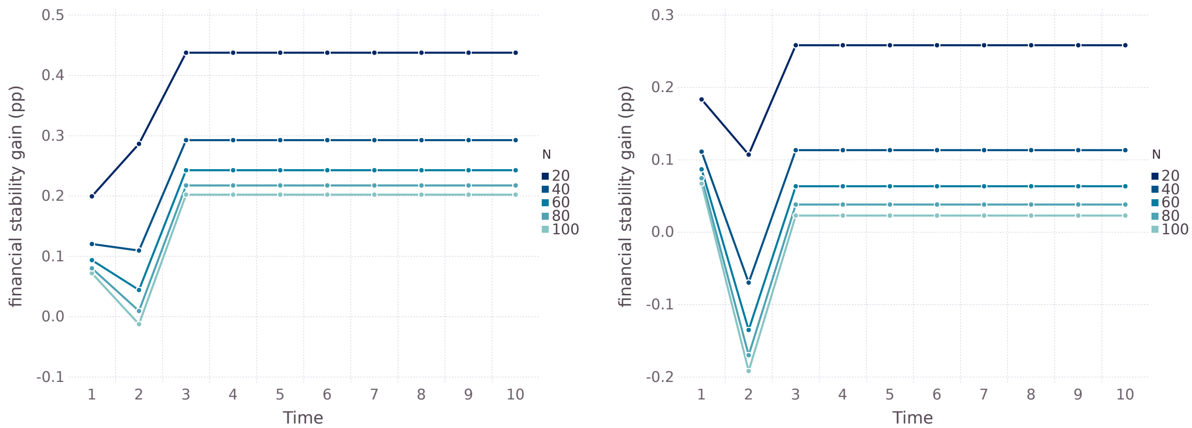
[27] Perotti and Suarez (2002) specifically look at the merger policy that promotes takeovers of failed banks by solvent banks and argue that this policy can reinforce financial stability by raising banks' expected profits and thus reducing their risk taking. However, I find that these bank mergers can undermine financial stability in the short run by looking at their effect on the equity ratios of the merged banks.

[28] In the model, when two identical banks with the same equity ratio merge, the increase in equity will more than offset the increase in loan quantity, leading to an increase in its equity ratio and a lower default probability even in the short run. Technically, each merged bank has greater market power and thus a higher loan quantity after the merger. However, the merged bank's loan quantity does not double compared to each individual bank's loan quantity before the merger due to the fall in aggregate loan quantity with less banking competition, while its equity doubles, so its equity ratio goes up in the short run.

[29] In this case, the inefficiency τ_m of the merged bank is the average of the two banks before the merger, which is 0.032, equivalent to the average bank inefficiency in the baseline calibration shown in Table 1.

Figure 3: Financial Stability Gain after Solvent Banks Merge with Distressed Banks

(a) Distribute if Equity Ratio > 0.072 (b) Distribute if Equity Ratio > 0.109



Note: The two graphs plot the average financial stability gain (in percentage points) across the merged banks, computed using (24), under different initial levels of N as shown in the legend. In graph (a) vs (b), half of the banks with an equity ratio of 0.072 vs 0.109 merge in period 1 with the other half distressed banks with zero equity, so N reduces to $\frac{N}{2}$ from period 1 onwards. The desired equity ratio κ^* is assumed to be 0.072 vs 0.109 in graph (a) vs (b).

merges with one distressed bank whose equity was wiped out in period 0.[30] Assume the inefficiency τ_m of the merged bank is the average inefficiency τ_j of the two banks before the merger, so the mean bank inefficiency $\bar{\tau}$ does not change with N.

The bank mergers in period 1 reduce the number of banks to $\frac{N}{2}$ from period 1 onwards, resulting in less banking competition. Consequently, the financial stability gain would be expected to increase due to the higher profit margin on performing loans that provides a buffer against loan losses (margin effect). The graphs in Figure 3, however, show the opposite in most cases. The graphs plot the average financial stability gain (in percentage points) of a merged bank after the bank mergers for different initial numbers of banks N before the mergers. As long as N is not too small (e.g., $N = 20$ in graph (a)), the financial stability gain falls after the bank mergers. This is because the short-run equity ratio effect (due to the drop in the merged bank's equity ratio) dominates the margin effect. Since the solvent bank does not inherit much equity from the distressed bank, the equity of the merged bank only increases a little after the merger. Meanwhile, the merged bank has greater market power and thus a larger loan quantity under less banking competition, so the equity ratio of the merged bank falls. The lower equity ratio of the merged bank in period 1 leads to a fall in financial stability gain in period 2. Since the margin effect is weaker with larger N (i.e.,

[30]Just before the merger in period 1, however, distressed banks also have some equity due to the realized profits in period 1.

more intense banking competition), the fall in financial stability gain is more noticeable for larger N.

Furthermore, when the initial equity of the solvent bank is larger, the short-run equity ratio effect is stronger, as shown in graph (b). This follows from (23), which shows that the short-run equity ratio effect is absent when the initial equity is zero. When the initial equity is larger, the increase in loan quantity caused by the merger has a larger impact on reducing the merged bank's equity ratio. As shown in graph (b), where solvent banks are assumed to have an initial equity ratio of 0.109,[31] even when N decreases from 20 to 10 after the bank mergers, the short-run equity ratio effect still dominates the margin effect and hence the financial stability gain falls in period 2. So in the short run, less banking competition can jeopardize financial stability due to a stronger short-run equity ratio effect relative to the static margin effect.

4.3 Efficiency Loss from Imperfect Banking Competition

This section quantifies the macroeconomic efficiency loss associated with imperfect banking competition in terms of the reduction in expected output and compares it with the financial stability gain. The macroeconomic efficiency loss from imperfect banking competition is computed as:

$$\text{Macroeconomic Efficiency Loss} = \frac{\mathrm{E}_t(y_{t+1}^{PC}) - \mathrm{E}_t(y_{t+1})}{\mathrm{E}_t(y_{t+1}^{PC})} \tag{26}$$

where $\mathrm{E}_t(y_{t+1}) = A(k_t^*)^\alpha$ is the expected output with imperfect banking competition when the loan rate is $R_{b,t}^*$ (15). Based on Proposition 1 in Section 2.3, the macroeconomic efficiency loss is larger with less banking competition due to a higher loan rate and thus a lower demand for physical capital and lower expected output.

To compare the financial stability gain with the macroeconomic efficiency loss, this section constructs a new measure of financial stability gain in real terms. The financial stability loss of a bank j is the part of the liabilities (deposits) that the bank defaults on when it goes bankrupt. More specifically, when the realized aggregate productivity shock is sufficiently low, i.e., $\epsilon_{t+1} < \bar{\epsilon}_{j,t+1}$, bank j's loss (or negative net profit $\pi_{j,t+1}^B$) is too large to be absorbed by its equity $n_{j,t}$, so $\pi_{j,t+1}^B(\epsilon_{t+1}) + n_{j,t}$ represents the unabsorbed loss of bank j or the amount of liabilities (deposits) that bank j defaults on. Since depositors are assumed to be protected by a full deposit guarantee, in this case, the government steps in to repay the bank's depositors. So the financial stability loss when bank j goes bankrupt is $\int_0^{\bar{\epsilon}_{j,t+1}} \left(\pi_{j,t+1}^B(\epsilon) + n_{j,t}\right) d\Gamma(\epsilon)$, which is negative.

[31] The mean equity ratio across EU banks from 1999-2014 is 0.109.

With perfect banking competition, the representative bank is more likely to default due to a lower profit margin and a lower equity ratio over time, so the expected loss in financial stability when the representative bank defaults is even larger. Hence, there is a financial stability gain of bank j from imperfect banking competition relative to perfect banking competition. The financial stability gain from imperfect banking competition normalized by the expected output under perfect banking competition is constructed as follows:

$$\text{Financial Stability Gain} = \frac{\sum_j \int_0^{\bar{\epsilon}_{j,t+1}} \left(\pi^B_{j,t+1}(\epsilon) + n_{j,t}\right) d\Gamma(\epsilon) - \int_0^{\bar{\epsilon}^{PC}_{t+1}} \left(\pi^B_{t+1}(\epsilon) + n_t\right) d\Gamma(\epsilon)}{\mathrm{E}_t(y^{PC}_{t+1})} \tag{27}$$

where $\Gamma(\epsilon)$ is the c.d.f. of the aggregate shock distribution and $\bar{\epsilon}^{PC}_{t+1}$, π^B_{t+1} and n_t represent the default threshold, net profit and equity of the representative bank under perfect banking competition respectively. The default threshold $\bar{\epsilon}^{PC}_{t+1}$ is calculated using the same method as shown in (25) in Section 4.1. The first term in the numerator of (27) represents the total financial stability loss of banks from imperfect banking competition and the second term shows the financial stability loss of the representative bank from perfect banking competition.

To quantify the importance of the financial stability gain relative to the macroeconomic efficiency loss from imperfect banking competition, I construct the following net gain measure:

$$\begin{aligned}\text{Net Gain} &= \text{Financial Stability Gain} - \text{Macroeconomic Efficiency Loss} \\ &= \frac{\sum_j \int_0^{\bar{\epsilon}_{j,t+1}} (\pi^B_{j,t+1}(\epsilon) + n_{j,t}) d\Gamma(\epsilon) - \int_0^{\bar{\epsilon}^{PC}_{t+1}} (\pi^B_{t+1}(\epsilon) + n_t) d\Gamma(\epsilon) - [\mathrm{E}_t(y^{PC}_{t+1}) - \mathrm{E}_t(y_{t+1})]}{\mathrm{E}_t(y^{PC}_{t+1})}\end{aligned} \tag{28}$$

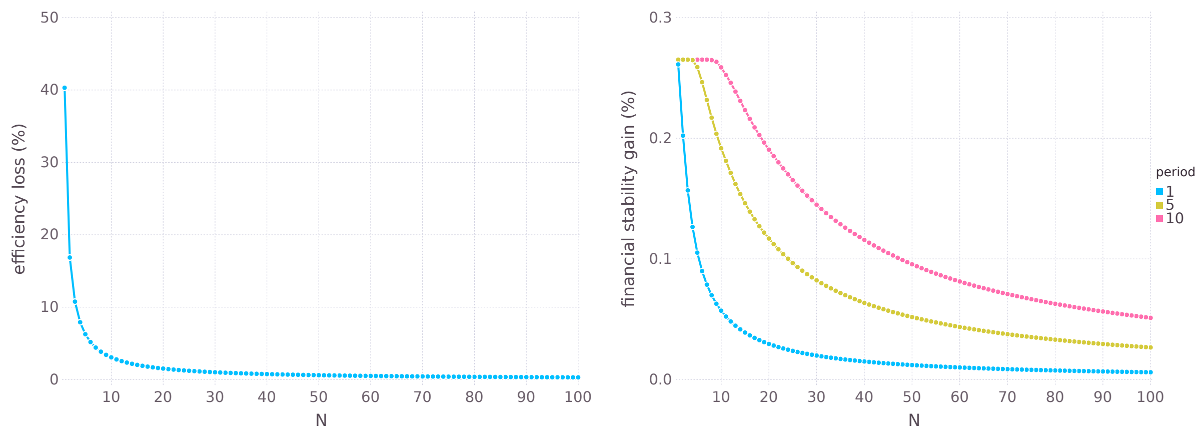
which is the difference between the financial stability gain (27) and the macroeconomic efficiency loss (26) resulting from imperfect banking competition. As can be seen from (28), the net gain measure is positive when the financial stability gain outweighs the macroeconomic efficiency loss.

Graph (a) in Figure 4 plots the macroeconomic efficiency loss across different number of banks N, which is computed following (26). As can be seen in graph (a), there is a large macroeconomic efficiency loss when there is very little competition (i.e., N is very small). For example, with a monopoly bank, the expected output is 40% lower than that with a perfectly competitive banking sector. When N increases, the loan rate becomes lower and approaches the the loan rate under perfect banking competition, which leads to a higher demand for physical capital and higher expected output.

Graph (b) in Figure 4 plots the output measure for the financial stability gain across different number of banks N and in three different time periods, which is computed following

Figure 4: Macroeconomic Efficiency Loss and Financial Stability Gain

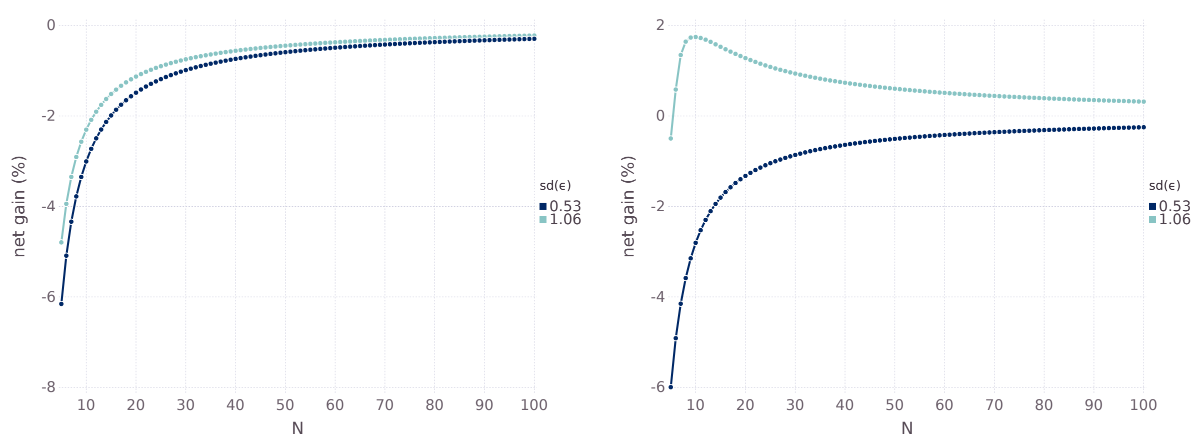
(a) Macroeconomic Efficiency Loss (b) Financial Stability Gain



Note: Graph (a) plots the macroeconomic efficiency loss (%) based on (26) across different levels of banking competition, with the number of banks N ranging from 1 to 100. Assuming there is no dividend distribution to shareholders, graph (b) plots the output measure for financial stability gain (%) based on (27) in period 1, 5, and 10 respectively, with the baseline calibration for the standard deviation of the aggregate shock ϵ distribution (i.e., $\text{sd}(\epsilon) = 0.53$) and different N ranging from 1 to 100.

Figure 5: Compare Macroeconomic Efficiency Loss with Financial Stability Gain

(a) Net Gain in Period 1 (b) Net Gain in Period 10



Note: Graphs (a) and (b) plot the net gain (%) based on (28) in period 1 and 10 respectively, for different number of banks N ranging from 5 to 100 and different standard deviations of the aggregate shock ϵ distribution, assuming there is no dividend distribution to shareholders.

(27). The graph is plotted under the baseline calibration for the standard deviation of the aggregate shock distribution of 0.53, which gives a bank default probability of around 2.13%. As the standard deviation increases during the volatile times, for instance, the financial stability gain also rises. As can be seen from graph (b), the financial stability gain increases over time due to bank equity accumulation under imperfect banking competition, which leads to higher bank equity ratios and thus lower bank default probabilities.

Graphs (a) and (b) in Figure 5 plot the net gain measure based on (28) with different number of banks N and different standard deviations of the distribution for the aggregate shock ϵ in period 1 and 10 respectively.[32] Assume banks are identical and have zero initial equity across different levels of N (including perfect banking competition when N approaches infinity). The differences in the average financial stability gain across different N in period 1 are caused by the margin effect. As can be seen from graph (a), when there is only the static margin effect, the net gain measure is negative and approaches zero as N tends to infinity. This is because in the absence of bank equity accumulation, the financial stability gain from imperfect banking competition is very small and is always outweighed by the macroeconomic efficiency loss. In this case, perfect banking competition is the best.

However, as banks under imperfect banking competition accumulate equity over time and have higher equity ratios than their counterparts under perfect banking competition, the net gain starts to turn positive during more volatile times when the standard deviation of the aggregate shock distribution is high, implying that the financial stability gain can outweigh the macroeconomic efficiency loss over time, as shown in graph (b). This also depends on the degree of imperfect banking competition.

More specifically, when there is very little competition (i.e., the number of banks is below 5), the macroeconomic efficiency loss is very large, as shown in graph (a) in Figure 4, which overrides any financial stability gain. As a result, even in the presence of bank equity accumulation, the net gain is still negative for small values of N. When there are more than six banks, the macroeconomic efficiency loss from imperfect banking competition is not too substantial and the financial stability gain due to equity accumulation over time can outweigh the macroeconomic efficiency loss, as can be seen from graph (b) in Figure 5. The net gain in period 10 is almost 2% when there are ten banks and aggregate volatility is high.

5 Data

Bank-level data on annual financial statements information are from Bankscope, which are used to calculate national concentration in the banking sector (i.e., Herfindahl Hirschman Index (HHI) and the 5-bank asset concentration ratio). The ECB Macroprudential database provides these two concentration measures estimated based on the total assets of credit

[32] In Figure 5, the number of banks N ranges from 5 to 100 to make the differences between the lines more noticeable.

institutions authorized in a given country, however, these measures are only available for EU countries. Using Bankscope data, I compute the two concentration measures for both EU and OECD countries.

There are two difficulties in computing the national banking concentration. First, some banks can have multiple statements with different consolidation code in Bankscope (i.e., unconsolidated statements U2 and consolidated statements C2).[33] To avoid double counting, only one of U2 or C2 should be kept for each bank. Keeping C2 means consolidated statements are used wherever possible when computing bank concentration. This may be appropriate if the controlled subsidiaries are domestic, so using consolidated statements may better reflect the national bank concentration. However, if the controlled subsidiaries are foreign, then using consolidated statements can overestimate the national concentration. In this paper, I choose to drop C2 and use unconsolidated statements wherever possible because the resulted measures align more closely with the ECB estimates. I use six different types of banks to compute the concentration, i.e., bank holding companies, commercial banks, cooperative banks, finance companies, real estate & mortgage banks, and savings banks, since this paper focuses on the types of banks whose main business is making loans. The types of banks that are dropped only account for around 5% of the total observations. Graphs for the two concentration measures over time for each EU or OECD countries in Figure 6 and 7 in Appendix D.3.1 show that in general, the ECB concentration measures have a smaller magnitude than my own calculation since the sample of banks used by ECB is likely to be larger than my sample.

Second, as noted by Uhde and Heimeshoff (2009), the sample of banks tends to increase over time in Bankscope, so the observed variation in concentration may be caused by the data coverage issue. To avoid this problem, I checked the data coverage for each EU or OECD country in each year using aggregate-level total assets and total credit data from the ECB and Bank for International Settlements (BIS) respectively. More specifically, for each EU country in each year, the sum of total assets of banks from Bankscope is divided by the total assets of all credit institutions from ECB and a larger ratio indicates better coverage. For each OECD country in each year, the sum of gross loans of banks from Bankscope is divided by the total credit of domestic banks (to private non-financial sector) from BIS. After plotting the concentration measures over time for each country, some extreme changes in concentration from one year to the next are easily spotted. Using the data on the shares of aggregate-level

[33] There are four main consolidation types in Bankscope, U1, U2, C1, and C2. U2 (U1) refers to the statement not integrating the statements of the possible controlled subsidiaries or branches of the concerned bank with (without) a consolidated companion in Bankscope. C2 (C1) refers to the statement of a mother bank integrating the statements of its controlled subsidiaries or branches with (without) an unconsolidated companion in Bankscope.

total assets and total credit, the number of banks in each year from Bankscope, and the ECB estimates on bank concentration for comparison, if the extreme changes in concentration in earlier years are caused by poor data coverage, then the country-year pairs are dropped. Table 9 in Appendix D.3.1 shows the Bankscope data coverage (mean values for the shares of aggregates over time) after dropping country-year pairs with poor data coverage. The data descriptions for each EU or OECD country including the number of observations and the number of different types of banks are shown in Table 8 in Appendix D.3.1.

Quarterly 5-year credit default swap (CDS) spreads for EU or OECD banks are from Thomson Reuters EIKON.[34] There are 218 unique banks in EU or OECD countries that have quarterly 5-year CDS spreads data available in the EIKON database. Each bank can have multiple CDS securities, with different seniorities, currencies, restructuring events, or data providers, which are uniquely identified in the database. Only one CDS security is kept for each bank. The cleaning procedures can be found in Appendix D.1.1. To analyse the relationship between banks' default probabilities proxied by the CDS spreads and their equity ratios, the cleaned CDS dataset is merged with the quarterly bank-level data on financial information from Bankscope.[35] The difficulty in merging the two datasets is that using the common identifiers (i.e., ISIN number and Ticker) can only allow me to match a limited number of banks since some banks are unlisted and some have missing ISIN or Ticker information in Bankscope. So for banks that cannot be matched by the identifiers, I manually match the banks from the two data sources using bank names. In this way, 174 banks can be matched, of which around 65% are commercial banks. I only keep 6 types of banks, i.e., bank holdings & holding companies, commercial banks, cooperative banks, finance companies, real estate & mortgage banks, and savings banks.[36] The period covered, number of observations in each quarter and other statistics for each country in the merged sample can be found in Table 10 in Appendix D.3.2.

Annual country-level variables such as real GDP growth rate and inflation rate (growth rate of GDP deflator) are from World Bank. Quarterly real GDP growth rates are from OECD. Dollar/euro exchange rates used to convert the total assets of credit institutions into dollar values are obtained from the Federal Reserve Bank of St. Louis (FRED). Country-level lending rates used for model calibration are monetary and financial institution (MFI) interest rates from ECB. Table 6 in Appendix D summarizes the data sources used in this

[34] Monthly spreads are also downloaded and averaged to give the quarterly spreads, which are very similar to the quarterly spreads and do not affect the results.

[35] Quarterly Bankscope data has a poor coverage as many banks do not report interim statements. However, this is not a problem if only looking at a small sample of large banks with CDS spreads data available.

[36] I drop 4 investment banks, 1 multi-lateral governmental banks, and 12 specialized governmental credit institutions. The final sample has 157 banks.

paper.

6 Empirical Evidence

The model predicts that when banks retain their profits to build up capital buffer, less banking competition improves financial stability. I empirically assess this prediction in two steps. The first step is to test whether banking competition has an impact on the change in bank equity, where bank concentration is used as an inverse proxy for banking competition based on the Cournot model. The second step is to test if banks' equity ratios are negatively related to banks' default probabilities proxied by the CDS spreads. Since only a small sample of large banks have CDS data available, quarterly bank-level data on financial statements are used to allow for more data points. Following these two steps, two main empirical specifications based on the theoretical model are shown in Section 6.1 and 6.2. Finally, in Section 6.3, I also assess the model prediction in one step by investigating the direct relationship between banking competition and banks' default probabilities.

6.1 Imperfect Bank Competition and Change in Bank Equity

Following the dynamics of bank's equity accumulation (9), bank j's equity $n_{j,t}$ is the sum of the equity in the previous period $n_{j,t-1}$ and the realized net profit net of any dividends $D_{j,t}$ paid.[37] Equivalently, after rearranging (9),

$$\frac{n_{j,t} + D_{j,t} - R_{t-1} n_{j,t-1}}{k_{j,t-1}} = R_{b,t-1} G(\epsilon_t) - (R_{t-1} + \tau_j) \tag{29}$$

where $G(\epsilon_t) \equiv [1 - F(\bar{\omega}_t(\epsilon_t))] + \frac{1-\mu}{\bar{\omega}_t(\epsilon_t)} \int_0^{\bar{\omega}_t(\epsilon_t)} \omega f(\omega) d\omega < 1$ is the fraction of $R_{b,t} k_{j,t}$ earned by bank j when the aggregate shock takes a value of ϵ_t. The right hand side of the equation (29) is the profit margin that is negatively related to the number of banks N, since the equilibrium loan rate decreases with N (Proposition 1). As a result, a lower N or higher concentration raises the pre-dividend change in equity $\frac{n_{j,t}+D_{j,t}-n_{j,t-1}}{k_{j,t-1}}$ by raising the equilibrium loan rate and hence the profit margin. The observed equity $n_{j,t}$ from the bank's balance sheet is net of the cash dividend. As long as some positive net profits are retained as equity, then

[37] In this paper, dividends $D_{j,t}$ are paid via cash or share repurchase, in which case the dividend payment leads to a reduction in total equity. In reality, another way to pay dividend is through stock dividend (issuing more shares), which does not reduce total equity and simply results in a reallocation of equity funds, that is, retained earnings decrease and paid-in-capital increases by the same amount. The reason to use total equity as a proxy for $n_{j,t}$ instead of retained earnings is because total equity is a more relevant measure for capital buffer and in addition, around 53% of observations for EU countries would be lost if using retained earnings.

the change in equity $\frac{n_{j,t}-n_{j,t-1}}{k_{j,t-1}}$ is expected to be larger for a smaller N or less banking competition. Based on equation (29), the following empirical specification is used in the baseline analysis:

$$\frac{n_{j,c,t}-n_{j,c,t-1}}{k_{j,c,t-1}} = \beta_0 + \beta_1 N_{c,t-1} + \boldsymbol{\beta'X} + \beta_j + \beta_t + \beta_c + \varepsilon_{j,c,t} \tag{30}$$

where j, c and t denote bank, country, and year respectively, and β_j, β_c, and β_t denote bank, country and year fixed effects respectively. $\boldsymbol{X}$ is a vector of bank-level and country-level control variables and $\boldsymbol{\beta'}$ is a row vector of the coefficients associated with each element in $\boldsymbol{X}$. In the baseline results shown in Table 2, the change in equity over lagged assets $\frac{n_{j,t}-n_{j,t-1}}{k_{j,t-1}}$ is used as the dependent variable. For robustness check, I also use $\frac{n_{j,t}+D_{j,t}-n_{j,t-1}}{k_{j,t-1}}$ as the dependent variable, where $D_{j,t}$ is proxied by cash dividends.

Since lagged bank concentration (proxy for $N_{c,t-1}$) is the main variable of interest that varies on country-year level, a pooled sample of different countries is used to control for the year fixed effects and exploit the cross-country variation.[38] Lagged number of banks $N_{c,t-1}$ is proxied by lagged Herfindahl Hirschman Index (HHI) or lagged 5-bank asset concentration ratio as one robustness check, as can be seen in Table 12 in Appendix E. The vector $\boldsymbol{X}$ includes lagged loan impairment charge to gross loans ratio at the bank-year level, inflation rate (measured by the growth rate of GDP deflator) and lagged real GDP growth rate at the country-year level. Summary statistics of the key variables are shown in Table 7 in Appendix D.3.2.

Table 2 shows the results by regressing the change in total equity over lagged total assets on lagged HHI, controlling for lagged loan impairment charge to gross loans ratio (loan impairment ratio), lagged real GDP growth rate and inflation rate (i.e., the growth rate of GDP deflator). The measure HHI (ECB) is directly obtained from the ECB, while HHI (Bankscope) is calculated from Bankscope annual data. Lagged loan impairment ratio and lagged GDP growth rate capture the variable $G(\epsilon_t)$ in equation (29) as they reflect the borrowers' ability to repay and hence the potential bank revenue loss due to non-performing loans. Controlling for inflation rate is because the dependent variable is not deflated. A higher inflation rate could inflate the change in equity in nominal terms and hence it should be positively related to the dependent variable. Banks from EU countries and OECD countries are used as two separate samples. Results without the controls are also shown in Table 2 for comparison.

It can be seen from Table 2 that bank concentration has a significant positive effect on the change in equity over lagged assets, as expected. Column 2 shows that when HHI (ECB)

[38] Regressions run separately for each country with year fixed effects will absorb the concentration variable.

Table 2: The Effect of Bank Concentration (HHI) on Change in Total Equity over Lagged Total Assets in EU and OECD Countries during 1999-2014

	(1) EU	(2) EU	(3) EU	(4) EU	(5) OECD	(6) OECD
L.HHI (ECB)	0.14***	0.11***				
	(0.02)	(0.02)				
L.HHI (Bankscope)			0.05***	0.04***	0.04***	0.03***
			(0.01)	(0.01)	(0.00)	(0.00)
L.loan impairment ratio		-0.06***		-0.07***		-0.15***
		(0.02)		(0.02)		(0.01)
L.GDP growth rate		0.11***		0.12***		0.06***
		(0.01)		(0.01)		(0.01)
inflation rate		0.11***		0.11***		0.12***
		(0.02)		(0.02)		(0.01)
Observations	44,419	44,419	45,033	45,033	199,317	199,317
No.banks	4,875	4,875	4,936	4,936	19,230	19,230
Adjusted R^2	0.270	0.279	0.265	0.275	0.105	0.110
Within R^2	0.004	0.015	0.001	0.015	0.001	0.008
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes

Bank-level clustered standard errors in parentheses

Data sources: Bankscope annual data, ECB, World Bank

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: The table shows the results from regressing the change in total equity over lagged total assets on lagged concentration index HHI, controlling for lagged loan impairment ratio (computed as loan impairment charge/gross loans), lagged real GDP growth rate (based on GDP in constant 2010 US dollar) and inflation rate (growth rate of GDP deflator). HHI (ECB) refers to the ECB estimate of HHI based on total assets of credit institutions in EU countries. HHI (Bankscope) is calculated using 6 types of banks (i.e., bank holding companies, commercial banks, cooperative banks, finance companies, real estate & mortgage banks, and savings banks) from Bankscope annual data.

measure increases by 0.01 (or 10% from its mean of 0.1 across EU countries), the change in bank equity for EU banks increases by 0.0011 (or 14% relative to the mean change in bank equity of around 0.008 for EU banks). HHI calculated using Bankscope data gives smaller coefficients than the ECB measure, which can be explained by the differences in the data sources. Figure 6 in Appendix D.3.2 compares the HHI from my own calculation with the HHI estimates from the ECB. As can be seen from Figure 6, although the two measures have similar time variation in many EU countries such as Czech Republic, France, Greece, Italy, Latvia, Lithuania, and Spain, in general, the HHI from the ECB tends to be smaller in mangnitude than the one calculated using Bankscope data, which is potentially due to a larger sample of credit institutions used by ECB.[39]

The signs of the other variables are also consistent with expectations. A higher loan impairment ratio lowers the equity due to loan losses, as a result, it is negatively related to the change in equity, as shown in Table 2. A higher GDP growth rate implies that more entrepreneurs would be able to repay their loans so it is positively related to change in equity. Inflation rate has a positive coefficient, as a higher inflation rate leads to a higher change in equity in nominal terms.

Results from four main robustness checks are shown in Appendix E. First, the regressions in Table 2 are re-run using 5-bank concentration ratio as an alternative inverse measure for $N_{c,t}$. As shown in Table 12, 5-bank ratio from ECB still has a highly significant positive effect on change in equity over lagged assets, while the measure calculated using Bankscope data is not significant in the sample of EU countries. Second, the samples of EU countries and OECD countries are further split into Eurozone countries, non-Eurozone EU countries, and non-EU OECD countries. As can be seen in Table 13, HHI still has a siginificant positive coefficient, except for the Euro area countries when HHI is calculated using Bankscope data, which may be because the ECB measure is more reliable. Besides, the results tend to suggest that HHI has a larger impact on the change in equity for non-Eurozone EU countries than the Eurozone countries. Third, instead of using post-dividend change in equity over lagged assets as the dependent variable, cash dividends are added back. That is, change in equity plus cash dividends over lagged assets $\frac{n_{j,t}+D_{j,t}-n_{j,t-1}}{k_{j,t-1}}$ is used as the dependent variable. As expected, HHI has a slightly larger impact on the pre-dividend change in equity, as shown in Table 14. Fourth, the sample over the period 1999-2014 is split into three different periods, 1999-2006, 2006-2014, and 2010-2014 for EU countries. Using the ECB measures for HHI and 5-bank concentration ratio, the results show that HHI is not significant during the pre-crisis period 1999-2006, as can be seen from Table 15.

6.2 Bank Equity Ratio and Default Probability

According to Proposition 5, banks' default probabilities are negatively related to banks' equity ratios. Using the CDS spreads to proxy for banks' default probabilities, the following empirical specification is used:

$$\text{CDS Spread}_{j,c,t} = \beta_0 + \beta_1 \frac{n_{j,c,t-1}}{k_{j,c,t-1}} + \boldsymbol{\beta' X} + \beta_j + \beta_c + \beta_t + \varepsilon_{j,c,t} \tag{31}$$

[39] The comparison between 5-bank concentration ratio from ECB and the ratio calculated using Bankscope data is shown in Figure 7 in Appendix D.3.2. Similar patterns are also observed for the 5-bank concentration ratio. In spite of a larger magnitude of the ratio calculated using Bankscope data, its time variation resembles that of the ECB measure in many EU countries.

Table 3: The Effect of Bank Equity Ratio on Bank CDS Spread in EU, Eurozone and OECD Countries during 2003-2016

	(1) EU	(2) EU	(3) Eurozone	(4) Eurozone	(5) OECD	(6) OECD
L.Equity Ratio	-0.34***	-0.25**	-0.32**	-0.23*	-0.33***	-0.33***
	(0.11)	(0.11)	(0.12)	(0.12)	(0.10)	(0.10)
L.Loan Impairment Ratio		0.59***		0.65***		0.56***
		(0.15)		(0.17)		(0.12)
L.GDP growth rate		-0.74***		-1.00***		-0.43***
		(0.18)		(0.18)		(0.14)
Observations	1,344	1,340	998	994	3,008	2,871
Number of Banks	50	50	38	38	108	104
Adjusted R^2	0.723	0.752	0.727	0.763	0.690	0.719
Within R^2	0.060	0.159	0.056	0.180	0.093	0.175
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Quarter Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes

Bank-level clustered standard errors in parentheses

Data sources: Thomson Reuters EIKON, Bankscope quarterly data, OECD

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: The table shows the results from regressing 5-year CDS spreads on banks' equity ratios, controlling for loan impairment charge to gross loans ratios, and real GDP growth rate. Bank, country and quarter fixed effects are included in all regressions. Quarterly data are used and all variables are in decimal places. Lagged explanatory variables are used. The sample consists of 6 types of banks (i.e., bank holding companies, commercial banks, cooperative banks, finance companies, real estate & mortgage banks, and savings banks).

where j, c, t denote bank, country and quarter respectively. $\boldsymbol{X}$ is a vector of bank-level and country-level control variables and $\boldsymbol{\beta'}$ is a row vector of the coefficients associated with each element in $\boldsymbol{X}$. β_j, β_c, and β_t denote bank, country and quarter fixed effects respectively. The main variable of interest, $\frac{n_{j,c,t-1}}{k_{j,c,t-1}}$, is proxied by lagged bank's equity to total assets ratio. The vector $\boldsymbol{X}$ includes lagged loan impairment charge to gross loans ratio at the bank-quarter level, and lagged real GDP growth rate. The summary statistics of the CDS spreads and bank equity ratios for each country can be seen in Table 11 in Appendix D.3.2.

The sample is divided into different groups of countries, i.e., EU, Eurozone and OECD countries. Using banks from different samples of countries, Table 3 shows that banks' equity ratios have a negative effect on their CDS spreads over the period of 2003-2016, controlling for lagged loan impairment charge to gross loans ratios and lagged real GDP growth rates.[40]

[40]Hasan, Liu and Zhang (2016) find that market leverage (book value of liabilities over the sum of book value of liabilities and market value of equity) has a positive effect on banks' CDS spreads using a sample of 161 global banks during 2001-2011. Similarly, Acosta Smith, Grill and Lang (2017) find that Tier 1 equity-to-total assets ratio has a negative effect on bank distress probabilities using data on a binary bank distress variable for EU banks during 2005-2014.

More specifically, focusing on columns 2, 4 and 6 in Table 3, when bank equity ratios increase from 10% to 11%, their CDS spreads would be reduced by around 23 to 33 basis points, which represents around 10% to 15% of the mean CDS spread of around 220 basis points across EU banks. Table 3 also shows that a higher loan impairment charge to gross loans ratio leads to an increase in the CDS spread since it indicates a higher proportion of non-performing loans. A higher real GDP growth rate that implies a higher repay capacity of borrowers leads to a lower CDS spread, as shown in Table 3.

Robustness checks using different time periods (i.e., 2003-2011 and 2011-2016) and different data frequency (i.e., annual data) are shown in Table 16 and 17 in Appendix E. Table 16 shows that equity ratios are not significant during 2003-2011 for EU countries and Eurozone countries. Using annual data instead of quarterly data does not change the results much if equity ratios are the only explanatory variable, as shown in Table 17, however, it tends to reduce the magnitude and the significance of the coefficients on equity ratios after controlling for other variables. Another robustness check is to use country-year fixed effects instead of the quarter fixed effects to control for any country-level macroeconomic variables that vary over time and any potential time trend in the equity ratio variable. As shown in Table 18 in Appendix E, the coefficients are significantly negative at 10% level, but the magnitude of the coefficients is smaller for EU and Eurozone countries.

6.3 Imperfect Bank Competition and Default Probability

In this section, I investigate whether imperfect banking competition lowers banks' default probabilities using a one-step approach. Table 4 shows the results from regressing banks' annual CDS spreads (proxy for banks' default probabilities) on bank concentration which is used as an inverse proxy for banking competition. In this section, annual CDS spreads (end of the fourth quarter data) are used since bank concentration has an annual frequency.

As can be seen from Table 4, the concentration index HHI or the 5-bank asset concentration ratio (both obtained from the ECB) has a significant negative effect on banks' CDS spreads during the post-crisis period (2011-2016).[41] More specifically, when HHI (5-bank concentration ratio) increases by 0.01 or 10% (2%) from its mean of 0.1 (0.6) across EU banks, the CDS spreads would be reduced by around 52 (16) basis points or 24% (7%) from its mean of 220 basis points across EU banks during 2011-2016. Bank concentration is only significant during the post-crisis period because the cross-country variation in CDS spreads during the pre-crisis period is small. The finding is consistent with the model prediction that

[41]The two different sample periods are divided by 2011 to make sure that the number of observations in each sample is roughly the same. The results are robust to dividing the whole sample by 2010 or 2012.

Table 4: Direct Relationship between CDS Spread and Concentration Measures in EU Countries

	(1) EU 2003-2016	(2) EU 2003-2011	(3) EU 2011-2016	(4) EU 2003-2016	(5) EU 2003-2011	(6) EU 2011-2016
L.HHI (ECB)	-0.08	-0.03	-0.52***			
	(0.06)	(0.09)	(0.11)			
L.Equity Ratio	-0.04	-0.33*	0.05	-0.05	-0.33*	0.02
	(0.05)	(0.19)	(0.08)	(0.05)	(0.19)	(0.08)
L.Loan Impairment Ratio	0.50**	1.12***	0.24	0.50**	1.12***	0.22
	(0.21)	(0.36)	(0.15)	(0.22)	(0.36)	(0.15)
L.GDP growth rate	-0.08	-0.31**	-0.06***	-0.08	-0.31**	-0.08***
	(0.08)	(0.14)	(0.02)	(0.08)	(0.14)	(0.02)
L.5-bank ratio (ECB)				-0.03	-0.02	-0.16***
				(0.03)	(0.03)	(0.05)
Observations	702	342	422	702	342	422
Number of Banks	76	65	76	76	65	76
Adjusted R^2	0.683	0.605	0.866	0.684	0.606	0.863
Within R^2	0.093	0.245	0.226	0.095	0.246	0.211
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes

Bank-level clustered standard errors in parentheses

Data sources: Thomson Reuters EIKON, ECB, Bankscope annual data, World Bank

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: The table shows the results from regressing 5-year CDS spreads on concentration index HHI or 5-bank concentration ratio, controlling for banks' equity ratios, loan impairment charge to gross loans ratios, and real GDP growth rate and including bank, country and year fixed effects. Annual data are used and all variables are in decimals. Lagged explanatory variables are used. The sample consists of EU banks and is divided into different sub-samples based on time periods.

in the presence of bank equity accumulation, imperfect banking competition improves financial stability by lowering banks' default probabilities. The signs of the other explanatory variables align with the expectation, as discussed in Section 6.2.

The result is robust to using the Bankscope measures of concentration, as shown in Table 19 in Appendix E. HHI still has a significant negative effect on banks' CDS spreads during the post-crisis period and 5-bank concentration ratio is significantly negative across all different sample periods. Results for OECD countries using the concentration measures from Bankscope are very similar to those shown in Table 19. Finally, excluding banks' equity ratios gives very similar results, despite the positive correlation between the equity ratio and bank concentration.

7 Conclusions

This paper provides new theoretical and empirical evidence on the effects of imperfect competition in the banking sector on banks' equity ratios and thereby financial stability, which is measured through banks' default probabilities. By building a model of imperfect banking competition featuring bank equity accumulation, this paper finds that less banking competition can lead to a large gain in financial stability, provided that banks retain the greater profits as equity over time. As a result, macroprudential policies, for example, by limiting banks' dividend distribution to shareholders, can help ensure a larger gain in financial stability from less banking competition.

However, in the short run, a reduction in banking competition can jeopardize financial stability by lowering banks' equity ratios. For instance, by allowing solvent banks to merge with distressed banks to improve financial stability after a crisis, the merged banks have greater market power and hence more loan assets, resulting in lower equity-to-assets ratios and therefore higher default probabilities.

In addition, this paper quantifies the financial stability gain from less banking competition compared to the macroeconomic efficiency loss. In doing so, I find that bank equity accumulation is important for understanding the trade-off between financial stability and macroeconomic efficiency. In the absence of bank equity accumulation, i.e., when there is only the static margin effect, the gain in financial stability from less banking competition is very limited and is always outweighed by the macroeconomic efficiency loss. In this case, perfect banking competition is the best. However, when banks accumulate equity over time, the financial stability gain from less banking competition can be large enough to outweigh the macroeconomic efficiency loss, depending on the degree of banking competition.

More specifically, when there is very little competition, the macroeconomic efficiency loss is very large and completely outweighs any financial stability gain. For example, with a monopoly bank, the expected output is 40% lower compared to that with a perfectly competitive banking sector. Moving away from the extreme case (i.e., when there are more than six banks), the financial stability gain from imperfect banking competition can outweigh the macroeconomic efficiency loss.

Using data for EU and OECD countries during 1999-2016, I find two sets of supporting evidence for the model's prediction that when banks use retained earnings to build up their capital buffer, less banking competition improves financial stability measured through banks' default probabilities. First, bank concentration, an inverse measure for banking competition, has a significant positive effect on the change in bank equity. Second, banks' equity ratios have a negative effect on their default probabilities, which are proxied by the credit default swap spreads. Combining these two steps into one step, I find that bank concentration has a significant negative effect on banks' default probabilities during the post-crisis period, which is consistent with the model prediction.

As a result, this paper has shown from both a theoretical and empirical perspective the importance of imperfect banking competition on financial stability.

Appendices

A Solving the Entrepreneur's Problem

A.1 The Slope of the Loan Demand Curve

Rewrite the entrepreneur's expected profit (4) as:

$$\begin{aligned}
&\mathrm{E}_t\left[\int_{\bar{\omega}_{t+1}(R_{b,t},k_t,\epsilon_{t+1})}^{\infty} \omega\epsilon_{t+1}Ak_t^{\alpha}dF(\omega) - \int_{\bar{\omega}_{t+1}(R_{b,t},k_t,\epsilon_{t+1})}^{\infty} R_{b,t}k_t dF(\omega)\right] \\
=&\mathrm{E}_t\left[\epsilon_{t+1}Ak_t^{\alpha}\int_{\bar{\omega}_{t+1}(R_{b,t},k_t,\epsilon_{t+1})}^{\infty} \omega f(\omega)d\omega - R_{b,t}k_t[1-F(\bar{\omega}_{t+1}(R_{b,t},k_t,\epsilon_{t+1}))]\right]
\end{aligned} \tag{32}$$

where $f(.)$ is the probability density function (p.d.f.) of the distribution for ω. Recall the condition that determines the entrepreneur's default threshold:

$$\bar{\omega}_{t+1} = \frac{R_{b,t}k_t^{1-\alpha}}{\epsilon_{t+1}A} \tag{2}$$

Since $\bar{\omega}_{t+1}$ is a function of k_t, when choosing k_t, the entrepreneur needs to consider the effect of k_t on their default probability $F(\bar{\omega}_{t+1})$. For simplicity, write $\bar{\omega}_{t+1}(R_{b,t}, k_t, \epsilon_{t+1})$ as $\bar{\omega}_{t+1}$ from here onwards. The gross loan rate $R_{b,t}$ is determined by the Cournot banking sector and taken as given by the entrepreneur. Then the first order condition of (32) with respect to k_t gives:

$$\begin{aligned}
\mathrm{E}_t\Bigg[\epsilon_{t+1}A\alpha k_t^{\alpha-1}\int_{\bar{\omega}_{t+1}}^{\infty} \omega f(\omega)d\omega - \epsilon_{t+1}Ak_t^{\alpha}\bar{\omega}_{t+1}f(\bar{\omega}_{t+1})\frac{\partial\bar{\omega}_{t+1}}{\partial k_t} \\
-R_{b,t}[1-F(\bar{\omega}_{t+1})] + R_{b,t}k_t f(\bar{\omega}_{t+1})\frac{\partial\bar{\omega}_{t+1}}{\partial k_t}\Bigg] = 0
\end{aligned} \tag{33}$$

Using $\epsilon_{t+1}Ak_t^{\alpha}\bar{\omega}_{t+1} = R_{b,t}k_t$ (2), (33) can be simplified to:

$$\mathrm{E}_t\left[\epsilon_{t+1}A\alpha k_t^{\alpha-1}\int_{\bar{\omega}_{t+1}}^{\infty} \omega f(\omega)d\omega - R_{b,t}[1-F(\bar{\omega}_{t+1})]\right] = 0 \tag{34}$$

Substitute $\epsilon_{t+1}Ak_t^{\alpha-1} = \frac{R_{b,t}}{\bar{\omega}_{t+1}}$ (2) into (34) and divide each term by $R_{b,t}$ to get:

$$\mathrm{E}_t\left[\frac{\alpha}{\bar{\omega}_{t+1}}\int_{\bar{\omega}_{t+1}}^{\infty} \omega f(\omega)d\omega - [1-F(\bar{\omega}_{t+1})]\right] = 0 \tag{35}$$

The optimal level of k_t for a given $R_{b,t}$ can be solved implicitly from this first order condition. The entrepreneur's default threshold can then be written as $\bar{\omega}_{t+1}(R_{b,t}, k_t(R_{b,t}), \epsilon_{t+1})$.

To check the second order condition, differentiate the LHS of (35) with respect to k_t again:

$$\begin{aligned}
&\mathrm{E}_t\left[-\frac{\alpha}{\bar{\omega}_{t+1}^2}\frac{\partial\bar{\omega}_{t+1}}{\partial k_t}\int_{\bar{\omega}_{t+1}}^{\infty}\omega f(\omega)d\omega - \frac{\alpha}{\bar{\omega}_{t+1}}\bar{\omega}_{t+1}f(\bar{\omega}_{t+1})\frac{\partial\bar{\omega}_{t+1}}{\partial k_t} + f(\bar{\omega}_{t+1})\frac{\partial\bar{\omega}_{t+1}}{\partial k_t}\right]\\
=&\mathrm{E}_t\left[-\frac{\alpha}{\bar{\omega}_{t+1}^2}\frac{\partial\bar{\omega}_{t+1}}{\partial k_t}\int_{\bar{\omega}_{t+1}}^{\infty}\omega f(\omega)d\omega + (1-\alpha)f(\bar{\omega}_{t+1})\frac{\partial\bar{\omega}_{t+1}}{\partial k_t}\right]\\
=&\mathrm{E}_t\left[-\frac{\alpha}{\bar{\omega}_{t+1}}(1-\alpha)k_t^{-1}\int_{\bar{\omega}_{t+1}}^{\infty}\omega f(\omega)d\omega + (1-\alpha)^2 f(\bar{\omega}_{t+1})\bar{\omega}_{t+1}k_t^{-1}\right]
\end{aligned} \tag{36}$$

where the last step uses $\epsilon_{t+1}\bar{\omega}_{t+1}Ak_t^{\alpha-1} = R_{b,t}$ (2), (3), and hence $\frac{\partial\bar{\omega}_{t+1}}{\partial k_t} = \frac{(1-\alpha)R_{b,t}k_t^{-\alpha}}{\epsilon_{t+1}A} = (1-\alpha)\bar{\omega}_{t+1}k_t^{-1}$. The second order condition is negative if:

$$\frac{\alpha}{1-\alpha} > \frac{\mathrm{E}_t[f(\bar{\omega}_{t+1})\bar{\omega}_{t+1}]}{\mathrm{E}_t\left[\frac{1}{\bar{\omega}_{t+1}}\int_{\bar{\omega}_{t+1}}^{\infty}\omega f(\omega)d\omega\right]} \tag{37}$$

When this condition is satisfied, a unique maximum k_t for a given $R_{b,t}$ can be solved from the first order condition (35). Under the calibration in this paper, this condition is always satisfied. Besides, this condition is satisfied if ω has a uniform distribution.

Using the first order condition (35) and defining $g(\bar{\omega}_{t+1}) \equiv \frac{\alpha}{\bar{\omega}_{t+1}}\int_{\bar{\omega}_{t+1}}^{\infty}\omega f(\omega)d\omega - [1 - F(\bar{\omega}_{t+1})]$, the slope of the loan demand curve (5) can be found using the implicit function theorem:

$$\frac{dk_t}{dR_{b,t}} = -\frac{\mathrm{E}_t\left[\frac{\partial g(\bar{\omega}_{t+1})}{\partial R_{b,t}}\right]}{\mathrm{E}_t\left[\frac{\partial g(\bar{\omega}_{t+1})}{\partial k_t}\right]} = -\frac{\mathrm{E}_t\left[\frac{\partial g(\bar{\omega}_{t+1})}{\partial\bar{\omega}_{t+1}}\frac{\partial\bar{\omega}_{t+1}}{\partial R_{b,t}}\right]}{\mathrm{E}_t\left[\frac{\partial g(\bar{\omega}_{t+1})}{\partial\bar{\omega}_{t+1}}\frac{\partial\bar{\omega}_{t+1}}{\partial k_t}\right]} = -\frac{\mathrm{E}_t\left[\frac{\partial g(\bar{\omega}_{t+1})}{\partial\bar{\omega}_{t+1}}\frac{k_t^{1-\alpha}}{\epsilon_{t+1}A}\right]}{\mathrm{E}_t\left[\frac{\partial g(\bar{\omega}_{t+1})}{\partial\bar{\omega}_{t+1}}\frac{(1-\alpha)k_t^{-\alpha}R_{b,t}}{\epsilon_{t+1}A}\right]} = -\frac{k_t}{(1-\alpha)R_{b,t}} < 0 \tag{5}$$

A.2 Relationship between the Entrepreneur's Default Threshold and the Gross Loan Rate

Use $\bar{\omega}_{t+1}(R_{b,t}, k_t(R_{b,t}), \epsilon_{t+1})$, where the optimal k_t is a function of $R_{b,t}$, and (5) to get (6):

$$\frac{d\bar{\omega}_{t+1}}{dR_{b,t}} = \frac{\partial\bar{\omega}_{t+1}}{\partial R_{b,t}} + \frac{\partial\bar{\omega}_{t+1}}{\partial k_t}\frac{dk_t}{dR_{b,t}} = \frac{k_t^{1-\alpha}}{\epsilon_{t+1}A} - \frac{(1-\alpha)k_t^{-\alpha}R_{b,t}}{\epsilon_{t+1}A}\frac{k_t}{(1-\alpha)R_{b,t}} = 0 \tag{6}$$

Hence, the gross loan rate does not affect the entrepreneur's default threshold when the entrepreneur is choosing k_t optimally. Alternatively, as can be seen from the total derivative of k_t with respect to $R_{b,t}$ (5), a one percent increase in $R_{b,t}$ leads to a $\frac{1}{1-\alpha}$ percent decrease in k_t. Given the expression for the threshold $\bar{\omega}_{t+1} = \frac{R_{b,t}k_t^{1-\alpha}}{\epsilon_{t+1}A}$ (2), changes in $R_{b,t}$ will be offset by the endogenous response of k_t, resulting in no overall impact of $R_{b,t}$ on $\bar{\omega}_{t+1}$. In other words, after substituting the optimal k_t for a given level of $R_{b,t}$ into the expression for $\bar{\omega}_{t+1}$, the default threshold $\bar{\omega}_{t+1}(R_{b,t}, k_t(R_{b,t}), \epsilon_{t+1})$ can be simplified to one that only depends on the aggregate shock, i.e., $\bar{\omega}_{t+1}(\epsilon_{t+1})$. This result holds more generally if the entrepreneur is assumed to have full liability, as shown below.

A.2.1 Extension: Entrepreneurs with Full Liability

With full liability, the entrepreneur maximizes the following expected profit with respect to physical capital k_t:

$$\mathrm{E}_t\left[\int_0^\infty \omega\epsilon_{t+1}Ak_t^\alpha dF(\omega) - R_{b,t}k_t\right] = Ak_t^\alpha - R_{b,t}k_t \tag{38}$$

where the expectation operator $\mathrm{E}_t[.]$ is taken over the distribution of the aggregate shock ϵ_{t+1} and $\mathrm{E}_t[\epsilon_{t+1}] = 1$. Take the first order condition of (38) with respect to k_t:

$$A\alpha k_t^{\alpha-1} - R_{b,t} = 0 \tag{39}$$

In this case, the expression of optimal capital demand can be explicitly found from (39), which is $k_t = \left(\frac{A\alpha}{R_{b,t}}\right)^{\frac{1}{1-\alpha}}$. The slope of the loan demand curve under full liability is identical to the limited liability case, which can be seen by differentiating the optimal capital demand with respect to $R_{b,t}$. In this case, using the functional form of the default threshold $\bar{\omega}_{t+1}$ (2) and the optimal capital demand, the entrepreneur's default threshold can be written as:

$$\bar{\omega}_{t+1} = \frac{\alpha}{\epsilon_{t+1}} \tag{40}$$

As can be seen, the entrepreneur's default threshold is still independent of $R_{b,t}$.

To see how the optimal k_t under full liability differs from the one under limited liability, the first order condition under limited liability (34) can be rewritten as:

$$A\alpha k_t^{\alpha-1} - R_{b,t} = \mathrm{E}_t\left[\epsilon_{t+1}A\alpha k_t^{\alpha-1}\int_0^{\bar{\omega}_{t+1}} \omega f(\omega)d\omega - R_{b,t}F(\bar{\omega}_{t+1})\right] \tag{41}$$

As can be seen, under limited liability of the entrepreneur, the RHS of (41) is no longer zero, unlike under full liability of the entrepreneur, when (39) holds. Since $A\alpha k_t^{\alpha-1} - R_{b,t}$ decreases in k_t, if the RHS is negative, then k_t under limited liability is larger than its counterpart under full liability.

Simplify the RHS of (41) using $\epsilon_{t+1} A k_t^{\alpha-1} = \frac{R_{b,t}}{\bar{\omega}_{t+1}}$ (2):

$$\mathrm{E}_t \left[\frac{\alpha R_{b,t}}{\bar{\omega}_{t+1}} \int_0^{\bar{\omega}_{t+1}} \omega f(\omega) d\omega - R_{b,t} F(\bar{\omega}_{t+1}) \right] = \mathrm{E}_t \left[R_{b,t} F(\bar{\omega}_{t+1}) \left(\frac{\alpha E[\omega | \omega < \bar{\omega}_{t+1}]}{\bar{\omega}_{t+1}} - 1 \right) \right] < 0 \tag{42}$$

which is negative as $\frac{E[\omega|\omega<\bar{\omega}_{t+1}]}{\bar{\omega}_{t+1}} < 1$. As a result, k_t under limited liability is larger than its counterpart under full liability. Hence, limited liability leads to a higher $\bar{\omega}_{t+1}$ and thus a higher default probability $F(\bar{\omega}_{t+1})$ than full liability.

B Solving the Bank's Problem

B.1 The Equilibrium Gross Loan Rate

Simplify bank j's net profit (7) using $\epsilon_{t+1} A k_t^{\alpha-1} = \frac{R_{b,t}}{\bar{\omega}_{t+1}}$ (2) to get:

$$\begin{aligned}
\pi^B_{j,t+1} =& \int_{\bar{\omega}_{t+1}(\epsilon_{t+1})}^{\infty} R_{b,t} k_{j,t} dF(\omega) + \frac{k_{j,t}}{k_t}(1-\mu) \int_0^{\bar{\omega}_{t+1}(\epsilon_{t+1})} \epsilon_{t+1} \omega A k_t^{\alpha} dF(\omega) \\
&- R_t(k_{j,t} - n_{j,t}) - \tau_j k_{j,t} - n_{j,t} \\
=& R_{b,t} k_{j,t} [1 - F(\bar{\omega}_{t+1}(\epsilon_{t+1}))] + k_{j,t}(1-\mu) \int_0^{\bar{\omega}_{t+1}(\epsilon_{t+1})} \epsilon_{t+1} \omega A k_t^{\alpha-1} dF(\omega) \\
&- R_t(k_{j,t} - n_{j,t}) - \tau_j k_{j,t} - n_{j,t} \\
=& R_{b,t} k_{j,t} [1 - F(\bar{\omega}_{t+1}(\epsilon_{t+1}))] + R_{b,t} k_{j,t} \frac{(1-\mu)}{\bar{\omega}_{t+1}(\epsilon_{t+1})} \int_0^{\bar{\omega}_{t+1}(\epsilon_{t+1})} \omega dF(\omega) \\
&- R_t(k_{j,t} - n_{j,t}) - \tau_j k_{j,t} - n_{j,t} \\
=& R_{b,t} k_{j,t} \left[[1 - F(\bar{\omega}_{t+1}(\epsilon_{t+1}))] + \frac{(1-\mu)}{\bar{\omega}_{t+1}(\epsilon_{t+1})} \int_0^{\bar{\omega}_{t+1}(\epsilon_{t+1})} \omega dF(\omega) \right] \\
&- R_t(k_{j,t} - n_{j,t}) - \tau_j k_{j,t} - n_{j,t} \\
=& R_{b,t} k_{j,t} G(\epsilon_{t+1}) - R_t(k_{j,t} - n_{j,t}) - \tau_j k_{j,t} - n_{j,t}
\end{aligned} \tag{8}$$

where

$$G(\epsilon_{t+1}) \equiv [1 - F(\bar{\omega}_{t+1}(\epsilon_{t+1}))] + \frac{1-\mu}{\bar{\omega}_{t+1}(\epsilon_{t+1})}\int_0^{\bar{\omega}_{t+1}(\epsilon_{t+1})} \omega f(\omega) d\omega \tag{43}$$
$$= [1 - F(\bar{\omega}_{t+1}(\epsilon_{t+1}))] + (1-\mu)\frac{E[\omega|\omega \leqslant \bar{\omega}_{t+1}(\epsilon_{t+1})]}{\bar{\omega}_{t+1}(\epsilon_{t+1})} F(\bar{\omega}_{t+1}(\epsilon_{t+1}))$$
$$= 1 - F(\bar{\omega}_{t+1}(\epsilon_{t+1}))\left[1 - (1-\mu)\frac{E[\omega|\omega \leqslant \bar{\omega}_{t+1}(\epsilon_{t+1})]}{\bar{\omega}_{t+1}(\epsilon_{t+1})}\right] < 1$$

$G(\epsilon_{t+1}) < 1$ since $\mu \in [0,1]$ and $\frac{E[\omega|\omega<\bar{\omega}_{t+1}(\epsilon_{t+1})]}{\bar{\omega}_{t+1}(\epsilon_{t+1})} < 1$. $G(\epsilon_{t+1})$ denotes the fraction of gross loan return $R_{b,t}k_{j,t}$ that can be obtained by bank j.

$\bar{\omega}_{t+1}$ is a function in terms of only the aggregate shock when the entrepreneur chooses k_t optimally, as shown in (6). Due to this result, it is shown below that bank j's choice of loan quantity $k_{j,t}$ does not affect the entrepreneur's default threshold $\bar{\omega}_{t+1}$ in this model, which greatly simplifies the bank's problem. Since the total loan demand k_t is equal to the total loan supply from the j banks, i.e., $k_t = k_{j,t} + \sum_{m\neq j} k_{m,t}$, it follows that under Cournot competition,

$$\frac{dk_t}{dk_{j,t}} = 1 \tag{44}$$

Hence, using the fact that $\bar{\omega}_{t+1}$ is independent of $R_{b,t}$ (6), the entrepreneur's default threshold is independent of bank j's loan quantity choice $k_{j,t}$ when the entrepreneur is choosing the optimal amount of borrowing:

$$\frac{d\bar{\omega}_{t+1}}{dk_{j,t+1}} = \frac{d\bar{\omega}_{t+1}}{dR_{b,t}}\frac{dR_{b,t}}{dk_t}\frac{dk_t}{dk_{j,t}} = 0 \tag{45}$$

A further implication from (44) is that the effect of $k_{j,t}$ on the gross loan rate is equivalent to the slope of the downward-sloping inverse demand curve for loans, that is,

$$\frac{dR_{b,t}}{dk_{j,t}} = \frac{dR_{b,t}}{dk_t}\frac{dk_t}{dk_{j,t}} = \frac{dR_{b,t}}{dk_t} \tag{46}$$

Using the above three key elements that a) $k_t = k_{j,t} + \sum_{m\neq j} k_{m,t}$, b) $\frac{dR_{b,t}}{dk_{j,t}} = \frac{dR_{b,t}}{dk_t}$ and c) $\frac{d\bar{\omega}_{t+1}}{dk_{j,t}} = 0$, take the first order condition of the expected net profit $E_t[\pi^B_{j,t+1}]$ based on (8) with respect to $k_{j,t}$:

$$\left(R_{b,t} + k_{j,t}\frac{dR_{b,t}}{dk_{j,t}}\right) \mathrm{E}_t\left[[1 - F(\bar{\omega}_{t+1}(\epsilon_{t+1}))] + \frac{1-\mu}{\bar{\omega}_{t+1}(\epsilon_{t+1})}\int_0^{\bar{\omega}_{t+1}(\epsilon_{t+1})} \omega f(\omega) d\omega\right] - R_t - \tau_j = 0 \tag{47}$$

Use (46) to replace $\frac{dR_{b,t}}{dk_{j,t}}$ and sum (47) over all N banks to get:

$$\left(NR_{b,t} + k_t\frac{dR_{b,t}}{dk_t}\right)\mathrm{E}_t\left[[1 - F(\bar{\omega}_{t+1}(\epsilon_{t+1}))] + \frac{1-\mu}{\bar{\omega}_{t+1}(\epsilon_{t+1})}\int_0^{\bar{\omega}_{t+1}(\epsilon_{t+1})}\omega f(\omega)d\omega\right] - NR_t - \sum_{j=1}^{N}\tau_j = 0 \tag{48}$$

Since banks have different intermediation costs τ_j, each of them has a different market share in the Cournot equilibrium, depending on their inefficiency indicated by τ_j. Unlike the symmetric case with identical banks where an equilibrium condition $k_{j,t} = \frac{k_t}{N}$ can be imposed, here it is necessary to solve for the equilibrium loan rate and the equilibrium aggregate loan quantity first before knowing the market share of each bank.

Use $\frac{dR_{b,t}}{dk_t} = -\frac{(1-\alpha)R_{b,t}}{k_t}$ from (5) and the definition of $G(\epsilon_{t+1})$ in (43) to simplify (48):

$$R_{b,t}\left(N - 1 + \alpha\right)\mathrm{E}_t\left[G(\epsilon_{t+1})\right] - NR_t - \sum_{j=1}^{N}\tau_j = 0 \tag{49}$$

Rearrange to get the equilibrium gross loan interest rate $R^*_{b,t}$ (15):

$$R^*_{b,t} = \frac{NR_t + \sum_{j=1}^{N}\tau_j}{\left(N - 1 + \alpha\right)\mathrm{E}_t\left[G(\epsilon_{t+1})\right]} = \frac{R_t + \bar{\tau}}{\left(1 - \frac{1-\alpha}{N}\right)\mathrm{E}_t[G(\epsilon_{t+1})]} \tag{15}$$

where $\bar{\tau} \equiv \frac{1}{N}\sum_{j=1}^{N}\tau_j$ denotes the mean marginal intermediation cost across the N banks. It can be seen that $R^*_{b,t} > R_t$ since $\left(1 - \frac{1-\alpha}{N}\right) \leqslant 1$ and $\mathrm{E}_t[G(\epsilon_{t+1})] < 1$.

B.2 Parameter Restriction on τ_j

Since τ_j is randomly drawn from an exogenous distribution and the number of banks N is exogenously given, there needs to be a restriction on the value of τ_j to ensure that each of the N banks makes a positive expected profit. More specifically, assume banks are subject to a participation constraint:[42]

$$R_{b,t}k_{j,t}\mathrm{E}_t[G(\epsilon_{t+1})] - R_t(k_{j,t} - n_{j,t}) - \tau_j k_{j,t} > R_t n_{j,t} \tag{50}$$

[42] Banks do not make entry decisions since this paper abstracts away from endogenous entry dynamics. For a given level of N, each operating bank's inefficiency or intermediation cost τ_j is assumed to be within the range that allows each bank to make a positive expected profit.

where $\mathrm{E}_t[G(\epsilon_{t+1})] = \mathrm{E}_t\left[[1 - F(\bar{\omega}_{t+1}(\epsilon_{t+1}))] + \frac{1-\mu}{\bar{\omega}_{t+1}(\epsilon_{t+1})}\int_0^{\bar{\omega}_{t+1}(\epsilon_{t+1})} \omega f(\omega) d\omega\right]$. The above condition means that bank j with equity $n_{j,t}$ has an incentive to operate only if the profit earned from lending is not less than the opportunity cost of its own funds. Simplify (50) to get:

$$R_t + \tau_j < R_{b,t}\mathrm{E}_t[G(\epsilon_{t+1})] \tag{51}$$

Substitute the equilibrium loan rate (15) to get:

$$R_t + \tau_j < \frac{R_t + \bar{\tau}}{(1 - \frac{1-\alpha}{N})} \tag{17}$$

which means bank j's marginal cost (the sum of the gross deposit rate and the marginal intermediation cost) cannot be larger than a factor $\frac{1}{(1-\frac{1-\alpha}{N})} > 1$ of the mean marginal cost across banks. Note that when banks have identical marginal intermediation cost (i.e., $\tau_j = \bar{\tau}\ \forall j$), the above condition is always satisfied given $\alpha < 1$.

B.3 Proof of Proposition 1

Assume the distribution for τ does not change with the number of banks, so the average marginal intermediation cost across banks $\bar{\tau} = \frac{1}{N}\sum_{j=1}^{N} \tau_j$ is an exogenous constant. This is a convenient assumption since the baseline framework focuses on the effect of changing competition (or number of banks) on variables of interest for a given distribution of bank efficiency. Differentiate the equilibrium loan rate (15) with respect to N:

$$\begin{aligned}\frac{dR_{b,t}^*}{dN} &= -\frac{R_t + \bar{\tau}}{(1 - \frac{1-\alpha}{N})^2 \mathrm{E}_t\left[G(\epsilon_{t+1})\right]}\frac{1-\alpha}{N^2} \\ &= -\frac{(1-\alpha)R_{b,t}^*}{N(N-1+\alpha)} < 0\end{aligned} \tag{52}$$

where the second step uses the equilibrium loan rate (15). It is straightforward to see that this result is identical to the symmetric case where banks have the same level of efficiency $\tau_j = \bar{\tau}\ \forall j$.

Given the equilibrium loan rate (15), the equilibrium total loan quantity k_t^* is also known. It can be shown that k_t^* increases in N:

$$\frac{dk_t^*}{dN} = \frac{dk_t^*}{dR_{b,t}^*}\frac{dR_{b,t}^*}{dN} = -\frac{k_t^*}{(1-\alpha)R_{b,t}^*}\frac{dR_{b,t}^*}{dN} = \frac{k_t^*}{N(N-1+\alpha)} > 0 \tag{53}$$

Using (1), it can be seen that the expected output is Ak_t^{α}, as entrepreneurs are ex ante identical. It follows from $\frac{dk_t^*}{dN} > 0$ that the expected output $A(k_t*)^\alpha$ in terms of the optimal k_t^* also increases in N.

B.3.1 Extension: Distribution Mean for τ Changes with N

When the distribution of the marginal intermediation cost τ is allowed to change with N, how the equilibrium loan rate $R_{b,t}^*$ changes with N depends on the efficiency of the new entrants. Using the expression for the equilibrium loan rate (15), the change in $R_{b,t}^*$ when N increases by one is:[43]

$$\begin{aligned}
R_{b,t}^*(N+1) - R_{b,t}^*(N) = &\left[(N+1)R_t + \sum_{j=1}^{N+1}\tau_j - NR_t - \sum_{j=1}^{N}\tau_j\right]\frac{1}{(N+\alpha)\mathrm{E}_t[G(\epsilon_{t+1})]} \\
&+ \left(NR_t + \sum_{j=1}^{N}\tau_j\right)\left[\frac{1}{(N+\alpha)\mathrm{E}_t[G(\epsilon_{t+1})]} - \frac{1}{(N-1+\alpha)\mathrm{E}_t[G(\epsilon_{t+1})]}\right] \\
=&\frac{(R_t + \tau_{N+1})}{(N+\alpha)\mathrm{E}_t[G(\epsilon_{t+1})]} - \frac{(NR_t + \sum_{j=1}^{N}\tau_j)}{(N+\alpha)(N-1+\alpha)\mathrm{E}_t[G(\epsilon_{t+1})]} \\
=&\frac{(N-1+\alpha)\tau_{N+1} - (1-\alpha)R_t - \sum_{j=1}^{N}\tau_j}{(N+\alpha)(N-1+\alpha)\mathrm{E}_t[G(\epsilon_{t+1})]}
\end{aligned} \tag{55}$$

where τ_{N+1} denotes the marginal intermediation cost of the new entrant. As can be seen, the sign of $R_{b,t}^*(N+1) - R_{b,t}^*(N)$ depends on the magnitude of the efficiency of the $(N+1)$-th bank, τ_{N+1}. This paper focuses on changes in the degree of market power from changes in competition by assuming that the distribution mean for τ is unaffected by N.

B.4 Proof of Proposition 2

Once the equilibrium loan rate and the equilibrium aggregate loan quantity are known, each bank j's equilibrium loan quantity $k_{j,t}^*$ (18) can be found by using $\frac{dR_{b,t}}{dk_{j,t}} = \frac{dR_{b,t}}{dk_t}$ (46), bank

[43] Using the product rule for discrete functions (sequences) $u(x)$ and $v(x)$, where x denotes the inputs for the discrete functions.

$$\Delta(u(x)v(x)) = \Delta u(x)\Delta v(x) + \Delta u(x)v(x) + u(x)\Delta v(x) = v(x+1)\Delta u(x) + u(x)\Delta v(x) \tag{54}$$

where $\Delta u(x) = u(x+1) - u(x)$ and $\Delta v(x) = v(x+1) - v(x)$ are the discrete counterparts of $\frac{du}{dx}$ and $\frac{dv}{dx}$. In this case, let $x = N$, $u(x) = NR_t + \sum_{j=1}^{N}\tau_j$, $v(x) = \frac{1}{(N-1+\alpha)\mathrm{E}_t[G(\epsilon_{t+1})]}$.

j's first order condition (47), $\frac{dk_t^*}{dR_{b,t}^*} = -\frac{k_t^*}{(1-\alpha)R_{b,t}^*}$ (5), and $R_{b,t}^*$ (15):

$$\begin{aligned} k_{j,t}^* &= \left[\frac{R_t + \tau_j}{\mathrm{E}_t\left[[1 - F(\bar{\omega}_{t+1}(\epsilon_{t+1}))] + \frac{1-\mu}{\bar{\omega}_{t+1}(\epsilon_{t+1})}\int_0^{\bar{\omega}_{t+1}(\epsilon_{t+1})} \omega f(\omega) d\omega\right]} - R_{b,t}^*\right] \frac{dk_t^*}{dR_{b,t}^*} \\ &= -\left[\frac{R_t + \tau_j}{\mathrm{E}_t\left[[1 - F(\bar{\omega}_{t+1}(\epsilon_{t+1}))] + \frac{1-\mu}{\bar{\omega}_{t+1}(\epsilon_{t+1})}\int_0^{\bar{\omega}_{t+1}(\epsilon_{t+1})} \omega f(\omega) d\omega\right]} - R_{b,t}^*\right] \frac{k_t^*}{(1-\alpha)R_{b,t}^*} \\ &= -\frac{k_t^*}{1-\alpha}\left[\frac{R_t + \tau_j}{\mathrm{E}_t\left[[1 - F(\bar{\omega}_{t+1}(\epsilon_{t+1}))] + \frac{1-\mu}{\bar{\omega}_{t+1}(\epsilon_{t+1})}\int_0^{\bar{\omega}_{t+1}(\epsilon_{t+1})} \omega f(\omega) d\omega\right] R_{b,t}^*} - 1\right] \\ &= \frac{k_t^*}{1-\alpha}\left[1 - \frac{(1 - \frac{1-\alpha}{N})(R_t + \tau_j)}{(R_t + \bar{\tau})}\right] \end{aligned} \tag{18}$$

Note that in a Cournot equilibrium with heterogeneous banks, bank j's equilibrium market share is no longer equal to $\frac{1}{N}$. According to (18), bank j's equilibrium market share $ms_{j,t}^*$ is:

$$ms_{j,t}^* \equiv \frac{k_{j,t}^*}{k_t^*} = \frac{1}{1-\alpha}\left[1 - \frac{(1 - \frac{1-\alpha}{N})(R_t + \tau_j)}{(R_t + \bar{\tau})}\right] \tag{56}$$

As can be seen from (56), if all banks have the same marginal intermediation cost (i.e., $\tau_j = \tau\ \forall j$), each bank j has a market share of $\frac{1}{N}$. In fact, when the bank has a below average marginal intermediation cost ($\tau_j < \bar{\tau}$), its market share is larger than $\frac{1}{N}$. Given the condition (17), bank j's equilibrium market share is positive. Since $ms_{j,t}^* > 0$ and $\sum_{j=1}^N ms_{j,t}^* = 1$, each bank's market share is less than 1.

Assume the distribution mean for τ does not change with N, it is shown below that each bank's market share falls with N:

$$\frac{dms_{j,t}^*}{dN} = -\frac{1}{1-\alpha}\frac{(\frac{1-\alpha}{N^2})(R_t + \tau_j)}{R_t + \bar{\tau}} = -\frac{R_t + \tau_j}{N^2(R_t + \bar{\tau})} < 0 \tag{57}$$

As can be seen, if bank j is more inefficient relative to the average bank (i.e., τ_j is larger than $\bar{\tau}$), then bank j's market share falls by more when N increases. When N is already large, the responsiveness of $ms_{j,t}^*$ to a further increase in N is much smaller.

B.5 Proof of Proposition 3

When banks have the same level of efficiency, each bank's loan quantity unambiguously decreases with the number of banks N for $N > 1$. In this case, use $k_{j,t}^* = ms_{j,t}^* k_t^*$, $\frac{dk_t^*}{dN} = \frac{k_t^*}{N(N-1+\alpha)}$ (53) and $ms_{j,t}^* = \frac{1}{N}$ to get:

$$\begin{aligned}\frac{dk^*_{j,t}}{dN} =& ms^*_{j,t}\frac{dk^*_t}{dN}+\frac{dms^*_{j,t}}{dN}k^*_t \\ =&\frac{1}{N}\frac{k^*_t}{N(N-1+\alpha)}-\frac{1}{N^2}k^*_t \\ =&\left(\frac{1}{N-1+\alpha}-1\right)\frac{k^*_t}{N^2}<0 \quad \text{if } N>1\end{aligned} \tag{58}$$

By contrast, when banks have different levels of efficiency, how each individual bank's loan quantity changes with N is unclear, depending on the balance between an increasing aggregate loan quantity k^*_t and the falling equilibrium market share when N increases (Proposition 2). Using $k^*_{j,t}=ms^*_{j,t}k^*_t$, the expressions for $ms^*_{j,t}$ (56), $\frac{dk^*_t}{dN}$ (53) and $\frac{dms_{j,t}}{dN}^*$ (57), it is shown below that the sign of $\frac{dk^*_{j,t}}{dN}$ is ambiguous:

$$\begin{aligned}\frac{dk^*_{j,t}}{dN} =& ms^*_{j,t}\frac{dk^*_t}{dN}+\frac{dms^*_{j,t}}{dN}k^*_t \\ =&\frac{k^*_{j,t}}{k^*_t}\frac{k^*_t}{N(N-1+\alpha)}-\frac{R_t+\tau_j}{N^2(R_t+\bar{\tau})}k^*_t \\ =&\frac{1}{1-\alpha}\left[1-\frac{(1-\frac{1-\alpha}{N})(R_t+\tau_j)}{(R_t+\bar{\tau})}\right]\frac{k^*_t}{N(N-1+\alpha)}-\frac{R_t+\tau_j}{N^2(R_t+\bar{\tau})}k^*_t \\ =&\frac{[R_t+\bar{\tau}-(1-\frac{1-\alpha}{N})(R_t+\tau_j)]k^*_t-\frac{N-1+\alpha}{N}(1-\alpha)(R_t+\tau_j)k^*_t}{(1-\alpha)(R_t+\bar{\tau})N(N-1+\alpha)} \\ =&\frac{[R_t+\bar{\tau}-(2-\alpha)(1-\frac{1-\alpha}{N})(R_t+\tau_j)]k^*_t}{(1-\alpha)(R_t+\bar{\tau})N(N-1+\alpha)}\end{aligned} \tag{59}$$

It follows from (59) that $\frac{dk^*_{j,t}}{dN}<0$ when the numerator is negative:

$$R_t+\bar{\tau}-(2-\alpha)\left(1-\frac{1-\alpha}{N}\right)(R_t+\tau_j)<0 \tag{60}$$

or equivalently after rearranging,

$$R_t+\tau_j>\frac{R_t+\bar{\tau}}{(2-\alpha)(1-\frac{1-\alpha}{N})} \tag{61}$$

Since $\frac{R_t+\bar{\tau}}{(2-\alpha)(1-\frac{1-\alpha}{N})}$ is strictly smaller than the upper bound $\frac{R_t+\bar{\tau}}{(1-\frac{1-\alpha}{N})}$ (17), there is a positive probability that $\frac{dk^*_{j,t}}{dN}$ is negative for some banks and positive for others depending on the bank's relative efficiency. More specifically, $\frac{dk^*_{j,t}}{dN}<0$ when

$$\frac{R_t+\bar{\tau}}{(2-\alpha)(1-\frac{1-\alpha}{N})}<R_t+\tau_j<\frac{R_t+\bar{\tau}}{(1-\frac{1-\alpha}{N})} \tag{62}$$

and $\frac{dk^*_{j,t}}{dN} > 0$ when

$$R_t + \tau_j < \frac{R_t + \bar{\tau}}{(2-\alpha)(1-\frac{1-\alpha}{N})} \tag{63}$$

Intuitively, although each bank's market share falls with N (Proposition 2), this effect of market share reduction can be offset by the increase in total loan quantity as N increases, leading to an increase in bank j's loan quantity. According to (57), the market shares of more efficient banks with low τ_j relative to the mean are less sensitive to changes in N. So an increase in aggregate loan quantity as N increases can be large relative to a small drop in market share of a more efficient bank, resulting in an increase in the bank's loan quantity.

B.6 Proof of Proposition 4

It can be shown that the effect of changes in $k^*_{j,t}$ in response to an increase in N is dominated by the effect of the fall in $R^*_{b,t}$, so the expected net profit $\mathrm{E}_t[\pi^B_{t+1}]$ decreases with N. Following (8), the expected net profit in equilibrium is:

$$\mathrm{E}_t[\pi^B_{j,t+1}] \equiv R^*_{b,t}k^*_{j,t}\mathrm{E}_t[G(\epsilon_{t+1})] - R_t(k^*_{j,t} - n_{j,t}) - \tau_j k^*_{j,t} - n_{j,t} \tag{64}$$

Differentiate $\mathrm{E}_t[\pi^B_{j,t+1}]$ with respect to N and use the expressions for $\frac{dR^*_{b,t}}{dN}$ (52) and $\frac{dk^*_{j,t}}{dN}$ (59) to get:

$$\begin{aligned}
\frac{d\mathrm{E}_t[\pi^B_{j,t+1}]}{dN} =& \frac{dR^*_{b,t}}{dN}k^*_{j,t}\mathrm{E}_t[G(\epsilon_{t+1})] + \frac{dk^*_{j,t}}{dN}\left(R^*_{b,t}\mathrm{E}_t[G(\epsilon_{t+1})] - R_t - \tau_j\right) \\
=& -\frac{(1-\alpha)R^*_{b,t}k^*_{j,t}\mathrm{E}_t[G(\epsilon_{t+1})]}{N(N-1+\alpha)} \\
&+ \left(\frac{k^*_{j,t}}{N(N-1+\alpha)} - \frac{(R_t+\tau_j)}{N^2(R_t+\bar{\tau})}k^*_t\right)\left(R^*_{b,t}\mathrm{E}_t[G(\epsilon_{t+1})] - R_t - \tau_j\right) \\
=& \frac{\alpha R^*_{b,t}k^*_{j,t}\mathrm{E}_t[G(\epsilon_{t+1})] - (R_t+\tau_j)k^*_{j,t}}{N(N-1+\alpha)} - \frac{(R_t+\tau_j)}{N^2(R_t+\bar{\tau})}k^*_t\left(R^*_{b,t}\mathrm{E}_t[G(\epsilon_{t+1})] - R_t - \tau_j\right) < 0
\end{aligned} \tag{65}$$

Proof for $\frac{d\mathrm{E}_t[\pi^B_{t+1}]}{dN} < 0$:

1) According to (51):

$$R^*_{b,t}\mathrm{E}_t[G(\epsilon_{t+1})] - R_t - \tau_j > 0 \tag{51}$$

2) Using $ms^*_{j,t}$ (56), the fact that $ms^*_{j,t} < 1$ gives:

$$\frac{(1-\frac{1-\alpha}{N})(R_t+\tau_j)}{(R_t+\bar{\tau})} > \alpha \tag{66}$$

Substitute $R^*_{b,t}\mathrm{E}_t[G(\epsilon_{t+1})] = \frac{R_t+\bar{\tau}}{1-\frac{1-\alpha}{N}}$ (15) into the above inequality and rearrange to get:

$$\alpha R^*_{b,t}k^*_{j,t}\mathrm{E}_t[G(\epsilon_{t+1})] - (R_t + \tau_j)k^*_{j,t} < 0 \tag{67}$$

B.7 Proof of Proposition 5

Given the predetermined equity $n_{j,t}$, bank j chooses the loan quantity $k_{j,t}$ to maximize $E_t[\pi^B_{j,t+1}]$. In the presence of an adverse aggregate shock in period $t+1$, the net profit $\pi^B_{j,t+1}$ can be negative and if the loss is too large to be absorbed by the equity $n_{j,t}$, the pre-dividend equity $n_{j,t} + \pi^B_{j,t+1}$ in period $t+1$ would be negative in which case bank j defaults. More specifically, if the realized value of the aggregate shock ϵ_{t+1} is below bank j's default threshold $\bar{\epsilon}_{j,t+1}$, then bank j becomes insolvent, where $\bar{\epsilon}_{j,t+1}$ is determined by the condition (21):

$$n_{j,t} + \pi^B_{j,t+1}(\bar{\epsilon}_{j,t+1}) = R^*_{b,t}k^*_{j,t}G(\bar{\epsilon}_{j,t+1}) - R_t(k^*_{j,t} - n_{j,t}) - \tau_j k^*_{j,t} = 0 \tag{21}$$

where $G(\bar{\epsilon}_{j,t+1}) \equiv \left[[1 - F(\bar{\omega}_{t+1}(\bar{\epsilon}_{j,t+1}))] + \frac{1-\mu}{\bar{\omega}_{t+1}(\bar{\epsilon}_{j,t+1})}\int_0^{\bar{\omega}_{t+1}(\bar{\epsilon}_{j,t+1})}\omega f(\omega)d\omega\right] < 1$. $G(\bar{\epsilon}_{j,t+1})$ is a fraction of the contractual gross loan revenue $R_{b,t}k_{j,t}$ that can be earned by bank j when the realized aggregate shock takes a value of $\bar{\epsilon}_{j,t+1}$. This condition shows that the pre-dividend equity in period $t+1$ is zero when the realized value of the aggregate shock is $\bar{\epsilon}_{j,t+1}$. It can be shown that $G'(\bar{\epsilon}_{j,t+1})$ is positive:

$$\begin{aligned}
G'(\bar{\epsilon}_{j,t+1}) &= -f(\bar{\omega}_{t+1})\frac{\partial\bar{\omega}_{t+1}}{\partial\bar{\epsilon}_{j,t+1}} - \frac{1-\mu}{\bar{\omega}^2_{t+1}}\frac{\partial\bar{\omega}_{t+1}}{\partial\bar{\epsilon}_{j,t+1}}\int_0^{\bar{\omega}_{t+1}}\omega f(\omega)d\omega + \frac{1-\mu}{\bar{\omega}_{t+1}}\bar{\omega}_{t+1}f(\bar{\omega}_{t+1})\frac{\partial\bar{\omega}_{t+1}}{\partial\bar{\epsilon}_{j,t+1}} \\
&= \frac{\partial\bar{\omega}_{t+1}}{\partial\bar{\epsilon}_{j,t+1}}\left[-f(\bar{\omega}_{t+1}) - \frac{1-\mu}{\bar{\omega}^2_{t+1}}\int_0^{\bar{\omega}_{t+1}}\omega f(\omega)d\omega + (1-\mu)f(\bar{\omega}_{t+1})\right] \\
&= -\frac{\partial\bar{\omega}_{t+1}}{\partial\bar{\epsilon}_{j,t+1}}\left[\frac{1-\mu}{\bar{\omega}^2_{t+1}}\int_0^{\bar{\omega}_{t+1}}\omega f(\omega)d\omega + \mu f(\bar{\omega}_{t+1})\right] > 0
\end{aligned} \tag{68}$$

where $\frac{\partial\bar{\omega}_{t+1}}{\partial\bar{\epsilon}_{j,t+1}} < 0$, as can be seen from the entrepreneur's ex post default threshold $\bar{\omega}_{t+1}(\bar{\epsilon}_{j,t+1}) = \frac{R_{b,t}k^{*1-\alpha}_{j,t}}{\bar{\epsilon}_{j,t+1}A}$ based on (2), when the realized aggregate shock is $\bar{\epsilon}_{j,t+1}$. Intuitively, a higher realized aggregate shock reduces the entrepreneur's default threshold and thus default probability. Hence, $G(.)$ increases in $\bar{\epsilon}_{j,t+1}$, implying higher realized aggregate shock raises the fraction of $R^*_{b,t}k^*_{j,t}$ that can be obtained by bank j. Bank's default condition (21) shows that when the realized aggregate shock is below $\bar{\epsilon}_{j,t+1}$, the loan revenue $R^*_{b,t}k^*_{j,t}G(\bar{\epsilon}_{j,t+1})$ is too low and hence the net profit is too negative to be absorbed by $n_{j,t}$ such that bank j has to default.

Banks have different default thresholds due to different marginal intermediation costs τ_j

and the predetermined equity $n_{j,t}$. Divide each term in (21) by $k_{j,t}$ to get (22):

$$R^*_{b,t}G(\bar{\epsilon}_{j,t+1}) - (R_t + \tau_j) + R_t \frac{n_{j,t}}{k^*_{j,t}} = 0 \tag{22}$$

Implicitly differentiate (22) with respect to the equity ratio $\kappa_{j,t} = \frac{n_{j,t}}{k^*_{j,t}}$ to get:

$$R^*_{b,t}G'(\bar{\epsilon}_{j,t+1}) \frac{d\bar{\epsilon}_{j,t+1}}{d\kappa_{j,t}} + R_t = 0 \tag{69}$$

Rearrange to get:

$$\frac{d\bar{\epsilon}_{j,t+1}}{d\kappa_{j,t}} = -\frac{R_t}{R^*_{b,t}G'(\bar{\epsilon}_{j,t+1})} < 0 \tag{70}$$

B.8 Proof of Proposition 6

As can be seen from (22), a change in the number of banks N can affect bank j's default threshold via the profit margin $[R_{b,t}G(\bar{\epsilon}_{j,t+1}) - (R_t + \tau_j)]$, which resembles the margin effect. A lower N raises $R_{b,t}$ and hence the profit margin for an exogenous marginal cost $(R_t + \tau_j)$, resulting in a lower default threshold (margin effect). The equity ratio $\frac{n_{j,t}}{k^*_{j,t}}$ present in (22) reflects the equity ratio effect. A higher equity ratio lowers the default threshold since the bank is still able to survive with a lower realized aggregate shock. A lower N can lead to a larger $k_{j,t}$ (Proposition 3) and thus a lower equity ratio $\frac{n_{j,t}}{k_{j,t}}$ since $n_{j,t}$ is predetermined. This short-run equity ratio effect tends to raise the bank's default threshold as N decreases, which opposes the margin effect. Note that if $n_{j,t} = 0$, the short-run equity ratio effect is absent and an increase in N unambiguously raises bank j's default threshold. A formal proof is shown below. Totally differentiate (22) with respect to N:

$$R^*_{b,t}G'(\bar{\epsilon}_{j,t+1}) \frac{d\bar{\epsilon}_{j,t+1}}{dN} + \frac{dR^*_{b,t}}{dN} G(\bar{\epsilon}_{j,t+1}) + R_t \frac{1}{k^*_{j,t}} \frac{dn_{j,t}}{dN} - R_t \frac{n_{j,t}}{(k^*_{j,t})^2} \frac{dk^*_{j,t}}{dN} = 0 \tag{71}$$

Rearrange to get (23):

$$\frac{d\bar{\epsilon}_{j,t+1}}{dN} = \frac{R_t \frac{n_{j,t}}{k^*_{j,t}} \frac{dk^*_{j,t}}{dN} \frac{1}{k^*_{j,t}} - \frac{dR^*_{b,t}}{dN} G(\bar{\epsilon}_{j,t+1}) - R_t \frac{1}{k^*_{j,t}} \frac{dn_{j,t}}{dN}}{R^*_{b,t}G'(\bar{\epsilon}_{j,t+1})} \tag{23}$$

Since equity in period t is predetermined and is not affected by changes in N in period t, $\frac{dn_{j,t}}{dN} = 0$. However, future equity levels will be affected by changes in N, so do future default probabilities. Hence, the last term in the numerator refers to the long-run equity ratio effect.

As can be seen from (23), when $n_{j,t} = 0$, the sign of $\frac{d\bar{\epsilon}_{j,t+1}}{dN}$ is unambiguously positive due to the margin effect. When $n_{j,t} \neq 0$, the sign of $\frac{d\bar{\epsilon}_{j,t+1}}{dN}$ is ambigous, as proved below.

Use the expression for $\frac{dk^*_{j,t}}{dN_t}$ (59) and $k^*_{j,t}$ (18) to get:

$$\begin{aligned}\frac{dk^*_{j,t}}{dN}\frac{1}{k^*_{j,t}} &= \frac{[R_t+\bar{\tau}-(2-\alpha)(1-\frac{1-\alpha}{N})(R_t+\tau_j)]k^*_t}{(1-\alpha)(R_t+\bar{\tau})N(N-1+\alpha)}\frac{1-\alpha}{k^*_t}\frac{R_t+\bar{\tau}}{R_t+\bar{\tau}-(1-\frac{1-\alpha}{N})(R_t+\tau_j)} \\ &= \frac{R_t+\bar{\tau}-(2-\alpha)(1-\frac{1-\alpha}{N})(R_t+\tau_j)}{N(N-1+\alpha)[R_t+\bar{\tau}-(1-\frac{1-\alpha}{N})(R_t+\tau_j)]}\end{aligned} \tag{72}$$

Substitute (72) and the expression for $\frac{dR^*_{b,t}}{dN}$ (52) into (23):

$$\begin{aligned}\frac{d\bar{\epsilon}_{j,t+1}}{dN} &= \frac{R_t\frac{n_{j,t}}{k^*_{j,t}}\frac{R_t+\bar{\tau}-(2-\alpha)(1-\frac{1-\alpha}{N})(R_t+\tau_j)}{N(N-1+\alpha)[R_t+\bar{\tau}-(1-\frac{1-\alpha}{N})(R_t+\tau_j)]}+\frac{(1-\alpha)R^*_{b,t}}{N(N-1+\alpha)}G(\bar{\epsilon}_{j,t+1})}{R^*_{b,t}G'(\bar{\epsilon}_{j,t+1})} \\ &= \frac{R_t\frac{n_{j,t}}{k^*_{j,t}}\frac{R_t+\bar{\tau}-(2-\alpha)(1-\frac{1-\alpha}{N})(R_t+\tau_j)}{N(N-1+\alpha)[R_t+\bar{\tau}-(1-\frac{1-\alpha}{N})(R_t+\tau_j)]}+\frac{(1-\alpha)}{N(N-1+\alpha)}\left[R_t(1-\frac{n_{j,t}}{k^*_{j,t}})+\tau_j\right]}{R^*_{b,t}G'(\bar{\epsilon}_{j,t+1})} \\ &= \frac{R_t\frac{n_{j,t}}{k^*_{j,t}}\frac{1}{N(N-1+\alpha)}\left[\frac{R_t+\bar{\tau}-(2-\alpha)(1-\frac{1-\alpha}{N})(R_t+\tau_j)}{[R_t+\bar{\tau}-(1-\frac{1-\alpha}{N})(R_t+\tau_j)]}-(1-\alpha)\right]+\frac{(1-\alpha)}{N(N-1+\alpha)}(R_t+\tau_j)}{R^*_{b,t}G'(\bar{\epsilon}_{j,t+1})} \\ &= \frac{R_t\frac{n_{j,t}}{k^*_{j,t}}\frac{\alpha(R_t+\bar{\tau})-(1-\frac{1-\alpha}{N})(R_t+\tau_j)}{R_t+\bar{\tau}-(1-\frac{1-\alpha}{N})(R_t+\tau_j)}+(1-\alpha)(R_t+\tau_j)}{N(N-1+\alpha)R^*_{b,t}G'(\bar{\epsilon}_{j,t+1})}\end{aligned} \tag{73}$$

where the second step uses (22). Since $G'(\bar{\epsilon}_{j,t+1}) > 0$ (68), $\frac{d\bar{\epsilon}_{j,t+1}}{dN}$ (73) is negative (short-run equity ratio effect dominates the margin effect) if the numerator of (73) is negative, or equivalently,

$$\frac{n_{j,t}}{k^*_{j,t}} > \frac{(1-\alpha)(R_t+\tau_j)[R_t+\bar{\tau}-(1-\frac{1-\alpha}{N})(R_t+\tau_j)]}{R_t[(1-\frac{1-\alpha}{N})(R_t+\tau_j)-\alpha(R_t+\bar{\tau})]} > 0 \tag{74}$$

where $R_t+\bar{\tau}-(1-\frac{1-\alpha}{N})(R_t+\tau_j) > 0$ (17) and $(1-\frac{1-\alpha}{N})(R_t+\tau_j)-\alpha(R_t+\bar{\tau}) > 0$ (66). Rearrange (19) to get:

$$\alpha(R_t+\bar{\tau}) < \left(1-\frac{1-\alpha}{N}\right)(R_t+\tau_j) < R_t+\bar{\tau} \tag{19}$$

So the ratio $\frac{R_t+\bar{\tau}-(1-\frac{1-\alpha}{N})(R_t+\tau_j)}{(1-\frac{1-\alpha}{N})(R_t+\tau_j)-\alpha(R_t+\bar{\tau})}$ on the right hand side of the inequality (74) can be larger or smaller than one depending on the value of τ_j. If τ_j is relatively large, the ratio is smaller and it is more likely for the inequality (74) to hold. This means when N is lower, the default thresholds of relatively inefficient banks are more likely to increase due to a stronger short-run equity ratio effect ($k_{j,t}$ increases more after a decrease in N) and a weaker margin effect (profit margin is smaller due to higher τ_j).

C Simulation

C.1 Reverse Bounded Pareto Distribution for τ

Suppose τ has a Pareto distribution, then the p.d.f. $f_\tau(\tau)$ and c.d.f. $F_\tau(\tau)$ are:

$$f_\tau(\tau) = \frac{a\tau_s^a}{\tau^{a+1}} \tag{75}$$

$$F_\tau(\tau) = 1 - \left(\frac{\tau_s}{\tau}\right)^a \tag{76}$$

where $\tau_s > 0$ is the scale parameter and $a > 0$ is the shape parameter and the support is $\tau \in [\tau_s, \infty)$. Bounded (truncated) Pareto distribution is a conditional distribution that results from restricting the domain of Pareto distribution. By restricting the domain of the Pareto distribution to $(L, H]$, the p.d.f. $f_{\tau B}(\tau)$ and c.d.f. $F_{\tau B}(\tau)$ of the bounded Pareto distribution are respectively:

$$f_{\tau B}(\tau) = \frac{f_\tau(\tau)}{F_\tau(H) - F_\tau(L)} = \frac{\frac{a\tau_s^a}{\tau^{a+1}}}{1 - \left(\frac{\tau_s}{H}\right)^a - [1 - \left(\frac{\tau_s}{L}\right)^a]} = \frac{aL^a\tau^{-a-1}}{1 - \left(\frac{L}{H}\right)^a} \tag{77}$$

$$F_{\tau B}(\tau) = \frac{F_\tau(\tau) - F_\tau(L)}{F_\tau(H) - F_\tau(L)} = \frac{1 - \left(\frac{\tau_s}{\tau}\right)^a - [1 - \left(\frac{\tau_s}{L}\right)^a]}{1 - \left(\frac{\tau_s}{H}\right)^a - [1 - \left(\frac{\tau_s}{L}\right)^a]} = \frac{1 - L^a\tau^{-a}}{1 - \left(\frac{L}{H}\right)^a} \tag{78}$$

where the support is $\tau \in (L, H]$. The bounded Pareto distribution is positively skewed with a long right tail in the domain of $(L, H]$. To generate a market share distribution that contains a few large banks and a lot of small banks, this distribution for τ needs to be reversed such that it is negatively skewed with a long left tail since small τ implies large equilibrium market share. So the p.d.f. of the bounded Pareto distribution is flipped around the y-axis and then shifted to the right by $L + H$, leading to a reverse bounded Pareto distribution that lies within the same domain $(L, H]$. Using (77), the p.d.f. of the reverse distribution $f_{\tau BR}(\tau)$ becomes:

$$f_{\tau BR}(\tau) \equiv f_{\tau B}(-\tau + H + L) = \frac{aL^a(H + L - \tau)^{-a-1}}{1 - \left(\frac{L}{H}\right)^a} \tag{79}$$

Hence, the c.d.f. of the reverse distribution $F_{\tau BR}(\tau)$ is:

$$F_{\tau BR}(\tau) = \int_L^\tau \frac{aL^a(H + L - \tau)^{-a-1}}{1 - \left(\frac{L}{H}\right)^a} d\tau = \frac{L^a(H + L - \tau)^{-a} - L^aH^{-a}}{1 - \left(\frac{L}{H}\right)^a} \tag{80}$$

τ_j is drawn from the reverse bounded Pareto distribution $F_{\tau BR}(\tau)$ with domain $(L, H]$. Applying the inverse-transform method, this distribution can be generated using a uniform distribution $Uniform[0, 1]$. Let U denote a random variable with the continuous uniform distribution over the interval [0, 1], τ_j can be drawn from $F^{-1}_{\tau BR}(U)$, where $F^{-1}_{\tau BR}(.)$ represents the inverse function. The inverse transform method can be used as long as there is an explicit expression for $F^{-1}_{\tau BR}(.)$ in closed form. Using the expression for (80),

$$U = \frac{L^a(H+L-\tau)^{-a} - L^a H^{-a}}{1-\left(\frac{L}{H}\right)^a} \tag{81}$$

Rearrange the above equation for τ:

$$\tau = H + L - \left[UL^{-a} - UH^{-a} + H^{-a}\right]^{-\frac{1}{a}} \tag{82}$$

In simulation, random numbers are first generated from a uniform distribution $U[0,1]$, then τ_j is obtained using (82).

C.2 Calibration

Table 5: Baseline Calibration of Parameters

Parameter	Value Germany
Number of banks N	60
Capital share α	0.3
Desired equity ratio κ^*	0.072
Collection cost μ	0.04
Support for bounded Pareto distribution of τ	[0.001, 0.04]
Shape for bounded Pareto distribution of τ	0.1
Mean of log-normal distribution of ω	-0.15
Variance of log-normal distribution of ω	0.3
Mean of log-normal distribution of ϵ	-0.14
Variance of log-normal distribution of ϵ	0.28

D Data

D.1 Data Cleaning

D.1.1 Credit Default Swaps from the Thomson Reuters

Banks with 5-year CDS traded are identified by their names or Ticker in EIKON database. From the download for all 5-year CDS data at a quarterly frequency, there are 306 banks from all countries and 218 unique banks in EU or OECD countries. Each bank can have multiple CDS securities, with different seniorities, currencies, restructuring events, or data providers, which are uniquely identified by RIC (Reuters instrument code) in EIKON database.[44] There are 4103 unique RIC (CDS securities) from all countries and 3534 unique RIC for banks in EU or OECD countries from the download.

After dropping the missing CDS midspread data (302 banks left), the following steps are taken to make sure only one CDS security is kept for each bank:

1) Keep only one type of seniority for each bank. There are 4 types of issue seniority: junior, secured, senior unsecured (67%) and subordinated (≈33%). The last two types account for the majority of the data points. For each bank, keep the seniority type that occurs most frequently throughout time to maximize the number of data points. After this step, only two types of seniority are left: senior unsecured (≈ 96%) and subordinated (≈ 4%), and 300 banks are left.

2) For each bank, keep the restructuring event that appears most frequently throughout time. After this step, 296 banks are left.

3) Keep only one type of currency for each bank. There are 18 different currencies, with Euro and US dollar accounting for approximately 46% and 40% of the data points respectively. For each bank, keep the currency that occurs most frequently throughout time. After this step, 4 types of currencies (Australian Dollar, British Pound Sterling, Euro, Japanese Yen, and US Dollar) and 292 banks are left.

4) Keep only one data contributor for each bank. There are 12 different data contributors. GFI FENICS (≈ 36%), Thomson Reuters EOD (≈ 24%), and Markit Intraday (≈ 11%) account for the majority of the data points, with numbers inside the brackets indicating their shares of the observations. Keep only one type of data contributor for each bank based on the number of observations. After this step, 8 different data contributors are left, with GFI FENICS accounting for around 78% of the data and Thomson Reuters EOD for around 14%. 289 banks are left and 205 are in EU or OECD countries.

[44] Restructuring event is one type of credit events that triggers settlement under the CDS contract. Restructuring event is a "soft event" as the loss to the owner of the specific bond referenced in the CDS contract is not obvious.

Out of these 205 banks, 174 can be matched to Bankscope. Using ISIN number and Ticker can only match a limited number of banks since some banks are unlisted. So I manually match the banks from EIKON to the identifier (bvdid) in Bankscope using bank names, ISIN number and Ticker.

D.2 Data Sources

Table 6: Data Sources

Data	Descriptions	Source
Concentration measures	HHI and 5-bank concentration ratio based on total assets of credit institutions	ECB
Concentration measures	HHI and 5-bank concentration ratio based on total assets of 6 types of banks	Bankscope annual statements, own calculation
Monetary and financial institutions (MFI) interest rates	harmonised monthly (annualised) lending rates and deposit rates on new business with an initial rate fixation period of 1 year	ECB
Credit default swap spreads	5-year CDS quarterly end spreads	Thomson Reuters EIKON
Quarterly bank-level variables	total assets, total equity	Bankscope quarterly statements
Annual bank-level variables	total assets, total equity, loan impairment charge, net income, etc.	Bankscope annual statements
Country-level macro variables	real GDP growth rate, inflation rate (growth rate of GDP deflator)	World Bank
Country-level macro variables	quarterly real GDP growth rate	OECD
Country-level total credit	total credit of domestic banks to private non-financial sector	BIS
Country-level total assets of credit institutions	total assets (in euros) of credit institutions including domestic banking groups and stand alone banks, foreign (EU and non-EU) controlled subsidiaries and foreign (EU and non-EU) controlled branches	ECB
Dollar/Euro exchange rate	used to convert the total assets of credit institutions in euros from the ECB into dollars	Federal Reserve Bank of St Louis (FRED)

D.3 Summary Statistics

D.3.1 Annual Bankscope Data

Table 7: Summary Statistics of Key Variables by Groups of Countries

	Mean	Median	Percentiles				Obs.
			1st	25th	75th	99th	
EU countries							
change in equity/lagged assets	0.01	0.00	-0.08	-0.00	0.01	0.17	50,482
loan impairment ratio	0.01	0.01	-0.03	0.00	0.01	0.08	51,326
GDP growth rate	0.01	0.02	-0.06	0.00	0.03	0.07	56,942
inflation rate	0.02	0.01	-0.00	0.01	0.02	0.07	56,942
HHI (ECB)	0.11	0.10	0.02	0.06	0.12	0.40	56,307
HHI (Bankscope)	0.17	0.15	0.04	0.10	0.21	0.52	56,942
5-bank ratio (ECB)	0.59	0.59	0.20	0.47	0.71	0.99	56,350
5-bank ratio (Bankscope)	0.72	0.74	0.34	0.61	0.85	1.00	56,934
OECD countries							
change in equity/lagged assets	0.01	0.00	-0.06	0.00	0.01	0.15	209,680
loan impairment ratio	0.00	0.00	-0.01	0.00	0.01	0.06	221,648
GDP growth rate	0.02	0.02	-0.05	0.01	0.03	0.05	232,203
inflation rate	0.02	0.02	-0.01	0.01	0.02	0.05	232,203
HHI (Bankscope)	0.16	0.14	0.01	0.08	0.20	0.52	232,203
5-bank ratio (Bankscope)	0.69	0.72	0.20	0.57	0.83	1.00	232,195

Note: The table shows the summary statistics of the key variables used in the regression of change in equity on concentration. Change in total equity over lagged total assets is the dependent variable. Loan impairment ratio is calculated as loan impairment charge over gross loans. Variables apart from the concentration measures and GDP growth rate are winsorized for the top and bottom 1% of the distribution by a given group of countries (i.e., variables in the upper part of the table are winsorized by the pooled sample of EU countries). Statistics are shown after the winsorization. Statistics for concentration measures (country-year level) are computed using country-year level data, although bank-year observations are shown under "Obs.".

Table 8: Data Description for EU/OECD Countries in Bankscope

Country	Period	Obs	Obs/Year	Commercial	Savings	Cooperative	BHC	Other
Australia	2005-2014	394	39	31	1	7	5	31
Austria	2000-2014	3,599	240	86	141	119	8	30
Belgium	1999-2014	963	60	53	16	9	11	24
Bulgaria	1999-2014	317	20	26	1	1	1	4
Canada	2010-2014	417	83	44	4	36	7	13
Chile	1999-2007	206	23	29	0	0	0	2
Croatia	1999-2014	567	35	50	1	1	0	16
Cyprus	1999-2014	225	14	22	1	2	4	0
Czech Republic	2004-2014	302	27	24	0	2	0	17
Denmark	1999-2014	1,654	103	66	60	10	5	20
Estonia	1999-2014	84	5	8	0	0	1	0
Finland	2005-2014	270	27	30	16	2	2	11
France	1999-2014	4,998	312	200	49	131	9	150
Germany	1999-2014	27,244	1,703	200	685	1,502	17	141
Greece	2005-2014	176	18	19	1	1	1	4
Hungary	1999-2014	411	26	38	1	1	0	22
Iceland	2003-2014	159	13	6	24	0	0	10
Ireland	2002-2014	253	19	21	0	0	4	27
Israel	1999-2014	187	12	17	0	0	1	3
Italy	2005-2014	6,282	628	143	53	508	14	66
Japan	1999-2014	10,621	664	175	0	673	33	65
Latvia	1999-2014	304	19	24	0	0	0	1
Lithuania	1999-2014	156	10	13	0	0	0	0
Luxembourg	1999-2014	1,229	77	132	2	2	11	11
Malta	2000-2014	131	9	12	1	1	0	2
Mexico	1999-2014	1,127	70	63	11	5	18	101
Netherlands	1999-2014	740	46	48	2	1	20	30
New Zealand	2006-2014	167	19	15	1	6	2	10
Norway	2006-2014	1,318	146	22	124	0	5	28
Poland	2004-2014	407	37	54	1	1	2	8
Portugal	2005-2014	648	65	28	84	4	7	14
Romania	1999-2014	312	20	31	3	1	0	7
Slovakia	2005-2014	142	14	14	2	0	1	6
Slovenia	2005-2014	183	18	15	2	2	0	5
South Korea	2010-2014	213	43	16	6	1	5	29
Spain	2005-2014	1,642	164	71	66	82	5	27
Sweden	1999-2014	1,387	87	34	81	1	10	25
Switzerland	1999-2014	5,372	336	216	251	10	28	24
Turkey	2006-2014	576	64	34	0	0	5	68
United Kingdom	2005-2014	2,316	232	145	4	1	44	143
United States	1999-2014	156,212	9,763	9,220	1,037	40	3,048	98

Note: "Obs" shows the total number of observations in a sample of six types of banks (i.e., bank holding companies, commercial banks, savings banks, cooperative banks, finance companies, and real estate & mortgage banks) for each country. "Obs/Year" shows the average number of observations in each year across the period covered in each country. The last five columns show the number of banks under each type category (i.e., commercial banks, savings banks, cooperative banks, bank holding companies and others). "Other" includes the other two types of banks.

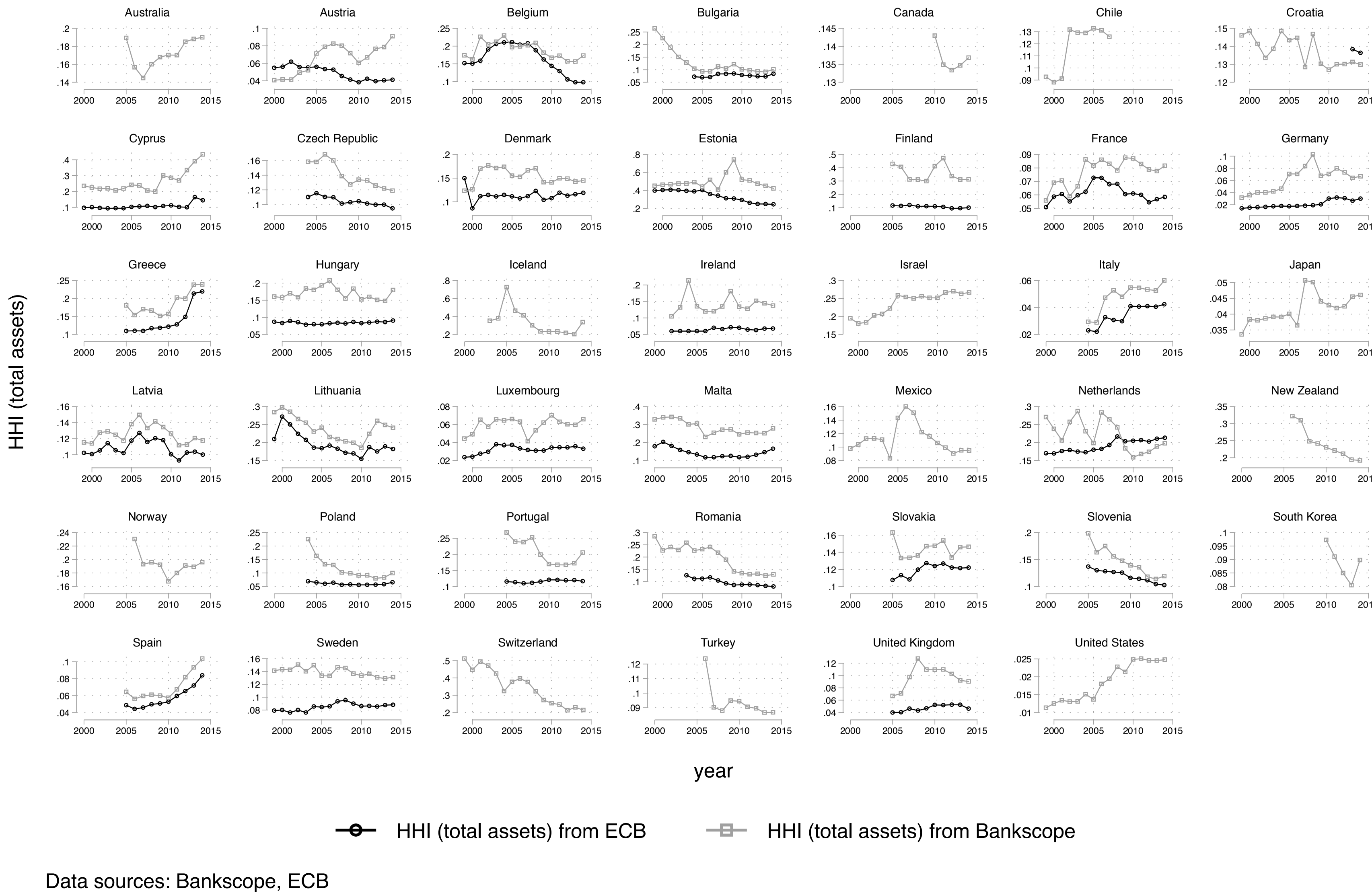
Table 9: Bankscope Data Compared with the Aggregates from ECB/BIS

Country	Share of Total Assets (ECB)	Period	Share of Total Credit (BIS)	Period
Australia		-	0.96	2005-2014
Austria	0.62	2008-2014	1.13	2000-2014
Belgium	1.12	2007-2014	2.25	1999-2014
Bulgaria	0.85	2007-2014		-
Canada		-	1.29	2010-2014
Chile		-	1.04	1999-2007
Croatia	0.95	2013-2014		-
Cyprus	0.61	2008-2014		-
Czech Republic	0.90	2007-2014	1.13	2004-2014
Denmark	1.13	2008-2014	1.31	1999-2014
Estonia	0.48	2008-2014		-
Finland	1.08	2007-2014	1.17	2005-2014
France	1.49	2007-2014	1.60	1999-2014
Germany	0.93	2008-2014	1.33	1999-2014
Greece	0.75	2008-2014	0.92	2005-2014
Hungary	0.63	2008-2014	0.72	1999-2014
Iceland		-		-
Ireland	0.60	2008-2014	1.19	2002-2014
Israel		-	0.95	1999-2014
Italy	1.04	2007-2014	1.21	2005-2014
Japan		-	1.25	1999-2014
Latvia	0.85	2008-2014		-
Lithuania	0.84	2007-2014		-
Luxembourg	0.72	2008-2014	4.76	2003-2014
Malta	0.36	2007-2014		-
Mexico		-	1.76	1999-2014
Netherlands	0.84	2008-2014	0.86	1999-2014
New Zealand		-	0.88	2006-2014
Norway		-	1.10	2006-2014
Poland	0.72	2007-2014	0.81	2004-2014
Portugal	0.94	2007-2014	0.96	2005-2014
Romania	0.75	2007-2014		-
Slovakia	0.71	2007-2014		-
Slovenia	0.82	2007-2014		-
South Korea		-	0.65	2010-2014
Spain	0.77	2008-2014	1.04	2005-2014
Sweden	0.64	2007-2014	0.99	1999-2014
Switzerland		-	1.09	1999-2014
Turkey		-	1.32	2006-2014
United Kingdom	0.75	2008-2014	1.49	2005-2014
United States		-	2.01	1999-2014

Data sources: Bankscope, ECB, BIS, FRED

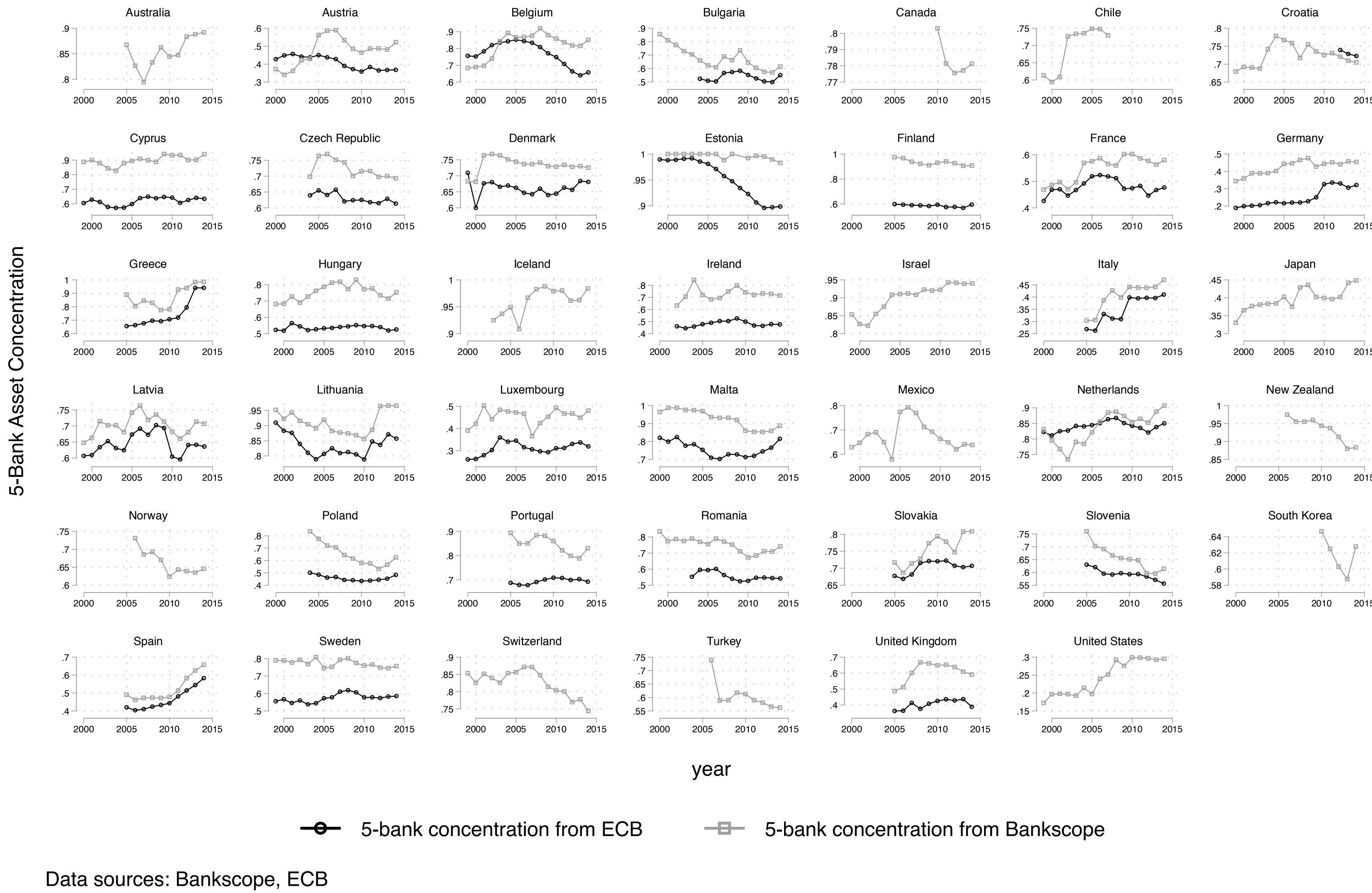
Note: Share of total assets (ECB) is computed by dividing total assets of all sampled banks in Bankscope data by total assets of credit institutions from ECB. The numbers reported are mean values over the period indicated in the third column. Share of total credit (BIS) is computed by dividing total gross loans of all sampled banks in Bankscope by total credit of domestic banks to private non-financial sector from BIS. The numbers reported are mean values over the period indicated in the last column.

Figure 6: Concentration Index (HHI) for EU and OECD Countries from 1999 to 2014



Note: The graphs plot the Herfindahl Hirschman Index (HHI) over time for each EU/OECD country. For EU countries where the measure is available from the ECB, the black line corresponds to the ECB measure over time. HHI from ECB is based on total assets of credit institutions, while HHI from Bankscope (grey line) is computed using total assets of 6 types of banks (i.e., bank holding companies, commercial banks, cooperative banks, savings banks, finance companies and real estate & mortgage banks).

Figure 7: 5-Bank Asset Concentration Ratio for EU and OECD Countries from 1999 to 2014



Note: The graphs plot the 5-bank asset concentration ratio over time for each EU/OECD country. For EU countries where the measure is available from the ECB, the black line corresponds to the ECB measure over time. 5-bank concentration ratio from ECB is based on total assets of credit institutions, while the concentration ratio from Bankscope (grey line) is computed using total assets of 6 types of banks (i.e., bank holding companies, commercial banks, cooperative banks, savings banks, finance companies and real estate & mortgage banks).

D.3.2 Merged Sample of Quarterly CDS Spreads and Bankscope Data

Table 10: Description for the Merged Sample
(quarterly CDS data merged with quarterly Bankscope data)

Country	Period	Obs	Obs/Year	Banks	Q1	Q2	Q3	Q4
Australia	2005-2016	154	13	8	0	68	3	83
Austria	2004-2016	126	10	5	25	36	29	36
Belgium	2005-2016	43	4	3	0	20	0	23
Canada	2010-2016	151	22	6	36	36	37	42
Chile	2011-2016	23	4	1	6	6	6	5
Denmark	2004-2016	49	4	1	13	12	12	12
Finland	2008-2016	17	2	1	0	9	0	8
France	2004-2016	230	18	11	22	91	25	92
Germany	2003-2016	208	15	7	44	62	43	59
Greece	2008-2016	108	12	4	26	28	27	27
Hungary	2008-2016	29	3	1	7	7	7	8
Ireland	2004-2016	86	7	4	0	42	1	43
Italy	2005-2016	234	20	6	48	62	58	66
Japan	2003-2016	368	26	19	53	134	49	132
Netherlands	2004-2016	133	10	7	11	56	4	62
Norway	2006-2016	81	7	2	19	22	20	20
Portugal	2004-2016	126	10	4	28	37	26	35
South Korea	2009-2016	157	20	7	34	41	33	49
Spain	2004-2016	260	20	9	53	72	57	78
Sweden	2005-2016	202	17	5	50	52	51	49
Switzerland	2003-2016	99	7	2	25	25	24	25
Turkey	2007-2016	86	9	4	15	26	20	25
United Kingdom	2004-2016	264	20	14	21	102	22	119
United States	2003-2016	983	70	26	239	244	248	252

Note: The table shows the number of observations for the merged sample of banks in OECD/EU countries. “Period” shows the time coverage for each country. “Obs” shows the total number of observations for each country. “Banks” shows the number of banks present in the sample. Columns Q1-Q4 show the number of total observations in each quarter.

Table 11: Summary Statistics of Key Variables in the Merged Sample by Country

	CDS (decimals)			Equity Ratio			
Country	1st	50th	99th	1st	50th	99th	Obs.
Australia	0.00	0.01	0.02	0.02	0.06	0.15	154
Austria	0.00	0.01	0.04	0.03	0.07	0.09	126
Belgium	0.00	0.01	0.05	0.03	0.05	0.09	43
Canada	0.00	0.01	0.04	0.03	0.05	0.06	151
Chile	0.01	0.01	0.02	0.07	0.09	0.09	23
Denmark	0.00	0.01	0.03	0.03	0.03	0.05	49
Finland	0.00	0.01	0.01	0.03	0.04	0.06	17
France	0.00	0.01	0.05	-0.00	0.03	0.10	230
Germany	0.00	0.01	0.04	0.01	0.03	0.07	208
Greece	0.01	0.09	0.26	-0.03	0.06	0.13	108
Hungary	0.01	0.01	0.02	0.09	0.12	0.15	29
Ireland	0.00	0.04	0.23	-0.01	0.04	0.12	86
Italy	0.00	0.01	0.06	0.03	0.07	0.14	234
Japan	0.00	0.01	0.04	0.02	0.06	0.09	368
Netherlands	0.00	0.01	0.18	0.02	0.04	0.34	133
Norway	0.00	0.01	0.02	0.04	0.05	0.07	81
Portugal	0.00	0.04	0.18	0.03	0.05	0.10	126
South Korea	0.01	0.01	0.02	0.05	0.07	0.12	157
Spain	0.00	0.02	0.10	0.02	0.06	0.08	260
Sweden	0.00	0.01	0.03	0.02	0.04	0.06	202
Switzerland	0.00	0.01	0.03	0.01	0.04	0.06	99
Turkey	0.02	0.03	0.08	0.10	0.12	0.15	86
United Kingdom	0.00	0.01	0.05	0.01	0.05	0.08	264
United States	0.00	0.01	0.08	0.05	0.10	0.20	983

Note: The table shows the summary statistics CDS spreads and equity-to-total assets ratio for each country in the merged sample. Numbers reported are in decimal places, e.g., CDS spread of 0.01 refers to 100 basis points, equity ratio of 0.02 means 20%. For each variable, the 1st, 50th, 99th percentiles are reported. “Obs.” shows the number of bank-quarter observations in each country.

E Robustness Checks

Table 12: The Effect of Concentration (5-Bank Asset Concentration Ratio) on Change in Total Equity over Lagged Total Assets during 1999-2014

	(1) EU	(2) EU	(3) EU	(4) EU	(5) OECD	(6) OECD
L.5-bank ratio (ECB)	0.06***	0.04***				
	(0.00)	(0.00)				
L.5-bank ratio (Bankscope)			-0.01	-0.00	0.02***	0.03***
			(0.00)	(0.00)	(0.00)	(0.00)
L.loan impairment ratio		-0.06***		-0.06***		-0.16***
		(0.02)		(0.02)		(0.01)
L.GDP growth rate		0.10***		0.13***		0.06***
		(0.01)		(0.01)		(0.01)
inflation rate		0.09***		0.12***		0.15***
		(0.02)		(0.02)		(0.01)
Observations	44,499	44,499	45,026	45,026	199,310	199,310
No.banks	4,915	4,915	4,936	4,936	19,230	19,230
Adjusted R^2	0.275	0.281	0.264	0.274	0.104	0.111
Within R^2	0.010	0.018	0.000	0.014	0.000	0.008
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes

Bank-level clustered standard errors in parentheses

Data sources: Bankscope annual data, ECB, World Bank

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: The table shows the results from regressing change in total equity over lagged total assets on lagged 5-bank asset concentration ratio and lagged loan impairment ratio (computed as loan impairment charge/gross loans), controlling for lagged real GDP growth and inflation rate (i.e., growth rate of GDP deflator). 5-bank ratio (ECB) is the ECB estimate of 5-bank asset concentration based on the total assets of credit institutions in EU countries. 5-bank ratio (Bankscope) is calculated using 6 types of banks (i.e., bank holding companies, commercial banks, cooperative banks, finance companies, real estate & mortgage banks, and savings banks) from annual Bankscope data.

Table 13: The Effect of Concentration (Herfindahl Hirschman Index HHI) on Change in Total Equity over Lagged Total Assets during 1999-2014

	(1) Euro	(2) Euro	(3) non-Euro	(4) non-Euro	(5) Euro	(6) Euro	(7) non-Euro	(8) non-Euro	(9) non-EU	(10) non-EU
L.HHI (ECB)	0.13***	0.11***	0.49***	0.29***						
	(0.02)	(0.02)	(0.13)	(0.11)						
L.HHI (Bankscope)					-0.02*	-0.03**	0.12***	0.15***	0.03***	0.04***
					(0.01)	(0.01)	(0.04)	(0.04)	(0.00)	(0.00)
L.loan impairment ratio		-0.06***		0.01		-0.06***		-0.01		-0.21***
		(0.02)		(0.07)		(0.02)		(0.05)		(0.01)
L.GDP growth rate		0.08***		0.04		0.09***		0.13***		0.07***
		(0.01)		(0.04)		(0.01)		(0.04)		(0.01)
inflation rate		0.16***		0.27***		0.17***		-0.02		-0.01
		(0.02)		(0.06)		(0.02)		(0.05)		(0.02)
Observations	40,060	40,060	4,359	4,359	40,060	40,060	4,973	4,973	155,634	155,634
No.banks	4,307	4,307	568	568	4,307	4,307	629	629	14,449	14,449
Adjusted R^2	0.277	0.286	0.325	0.333	0.274	0.284	0.296	0.298	0.098	0.103
Within R^2	0.004	0.017	0.008	0.021	0.000	0.015	0.005	0.008	0.001	0.007
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Bank-level clustered standard errors in parentheses

Data sources: Bankscope annual data, ECB, World Bank

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: The table shows the results from regressing change in total equity over lagged total assets on lagged concentration index HHI and lagged loan impairment ratio (computed as loan impairment charge/gross loans), controlling for lagged real GDP growth and inflation rate (i.e., growth rate of GDP deflator). HHI (ECB) is the ECB estimate of HHI based on the total assets of credit institutions in EU countries. HHI (Bankscope) is calculated using 6 types of banks (i.e., bank holding companies, commercial banks, cooperative banks, finance companies, real estate & mortgage banks, and savings banks) from annual Bankscope data. The samples are split into different groups of countries. Euro refers to Eurozone countries. Non-Euro refers to non-eurozone EU countries and non-EU refers to non-EU OECD countries.

Table 14: The Effect of Concentration (Herfindahl Hirschman Index HHI) on Pre-dividend Change in Equity over Lagged Total Assets during 1999-2014

	(1) EU	(2) EU	(3) EU	(4) EU	(5) OECD	(6) OECD
L.HHI (ECB)	0.16***	0.12***				
	(0.02)	(0.02)				
L.HHI (Bankscope)			0.06***	0.04***	0.05***	0.04***
			(0.01)	(0.01)	(0.00)	(0.00)
L.loan impairment ratio		-0.07***		-0.07***		-0.19***
		(0.02)		(0.02)		(0.01)
L.GDP growth rate		0.11***		0.11***		0.05***
		(0.01)		(0.01)		(0.01)
inflation rate		0.13***		0.13***		0.14***
		(0.02)		(0.02)		(0.01)
Observations	44,340	44,340	44,950	44,950	199,129	199,129
No.banks	4,870	4,870	4,930	4,930	19,223	19,223
Adjusted R^2	0.290	0.298	0.285	0.295	0.178	0.184
Within R^2	0.004	0.016	0.002	0.015	0.001	0.009
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes

Bank-level clustered standard errors in parentheses

Data sources: Bankscope annual data, ECB, World Bank

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: The table shows the results from regressing pre-dividend change in equity (i.e., change in equity plus the cash dividends) over lagged total assets on lagged concentration index HHI and lagged loan impairment cost (computed as loan impairment charge/gross loans), controlling for lagged real GDP growth and inflation rate (i.e., growth rate of GDP deflator). HHI (ECB) is the ECB estimate of HHI based on the total assets of credit institutions in EU countries. HHI (Bankscope) is calculated using 6 types of banks (i.e., bank holding companies, commercial banks, cooperative banks, finance companies, real estate & mortgage banks, and savings banks) from annual Bankscope data.

Table 15: The Effect of Concentration (Herfindahl Hirschman Index HHI) on Change in Equity over Lagged Total Assets during 1999-2014

	(1) EU 1999-2006	(2) EU 2006-2014	(3) EU 2010-2014	(4) EU 1999-2006	(5) EU 2006-2014	(6) EU 2010-2014
L.HHI (ECB)	0.01	0.18***	0.13***	0.01	0.14***	0.12***
	(0.03)	(0.03)	(0.04)	(0.03)	(0.02)	(0.04)
L.loan impairment ratio				-0.03	-0.05**	0.13***
				(0.03)	(0.02)	(0.02)
L.GDP growth rate				0.02	0.09***	0.01
				(0.04)	(0.01)	(0.02)
inflation rate				-0.01	0.16***	-0.04
				(0.04)	(0.02)	(0.04)
Observations	16,771	30,970	17,176	16,771	30,970	17,176
No.banks	3,111	4,322	3,818	3,111	4,322	3,818
Adjusted R^2	0.350	0.243	0.220	0.350	0.253	0.226
Within R^2	0.000	0.004	0.001	0.000	0.018	0.009
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes

Bank-level clustered standard errors in parentheses

Data sources: Bankscope annual data, ECB, World Bank

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: The table shows the results from regressing change in total equity over lagged total assets on lagged concentration index HHI and lagged loan impairment cost (computed as loan impairment charge/gross loans), controlling for lagged real GDP growth and inflation rate (i.e., growth rate of GDP deflator). HHI (ECB) is the ECB estimate of HHI based on the total assets of credit institutions in EU countries. The sample is divided into different subgroups conditioning on time period.

Table 16: The Effect of Bank Equity Ratio on Bank CDS Spread during Different Time Periods

	(1) EU 2003-2011	(2) EU 2011-2016	(3) Eurozone 2003-2011	(4) Eurozone 2011-2016	(5) OECD 2003-2011	(6) OECD 2011-2016
L.Equity Ratio	-0.14	-0.34***	-0.13	-0.32**	-0.38**	-0.33***
	(0.16)	(0.12)	(0.17)	(0.12)	(0.17)	(0.10)
L.Loan Impairment Ratio	2.40***	0.26	2.94**	0.34*	0.99**	0.18
	(0.83)	(0.17)	(1.12)	(0.18)	(0.39)	(0.16)
L.GDP growth rate	-0.64***	-0.95***	-0.84***	-1.35***	-0.44**	-0.52***
	(0.19)	(0.25)	(0.17)	(0.26)	(0.18)	(0.15)
Observations	582	862	434	636	1,195	1,933
Number of Banks	38	47	29	35	83	101
Adjusted R^2	0.685	0.824	0.708	0.831	0.641	0.819
Within R^2	0.164	0.197	0.181	0.236	0.153	0.163
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Quarter Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes

Bank-level clustered standard errors in parentheses

Data sources: Thomson Reuters EIKON, Bankscope quarterly data, OECD

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: The table shows the results from regressing 5-year CDS spreads on banks' equity ratios, controlling for loan impairment charge to gross loans ratios, and real GDP growth rate. Bank, country and quarter fixed effects are included in all regressions. Quarterly data are used and all variables are in decimal places. Lagged explanatory variables are used. The sample is divided into different subgroups according to regions and time periods.

Table 17: The Effect of Bank Equity Ratio on Bank CDS Spread during 2003-2016 Using Annual Data

	(1) EU	(2) EU	(3) Eurozone	(4) Eurozone	(5) OECD	(6) OECD
L.Equity Ratio	-0.21***	-0.05	-0.20***	-0.02	-0.20***	-0.08*
	(0.07)	(0.06)	(0.07)	(0.07)	(0.05)	(0.04)
L.Loan Impairment Ratio		0.43*		0.49*		0.48**
		(0.25)		(0.28)		(0.22)
L.GDP growth rate		-0.29**		-0.34**		-0.16**
		(0.11)		(0.14)		(0.07)
Observations	628	627	461	461	1,181	1,145
Number of Banks	74	74	54	54	144	141
Adjusted R^2	0.634	0.675	0.640	0.684	0.632	0.667
Within R^2	0.028	0.140	0.025	0.149	0.041	0.135
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes

Bank-level clustered standard errors in parentheses

Data sources: Thomson Reuters EIKON, Bankscope annual data, World Bank

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: The table shows the results from regressing 5-year CDS spreads on banks' equity ratios, controlling for loan impairment charge to gross loans ratios, and real GDP growth rate. Bank, country and year fixed effects are included in all regressions. Annual data are used and all variables are in decimal places. Lagged explanatory variables are used. The sample is divided into different subgroups according to regions.

Table 18: The Effect of Bank Equity Ratio on Bank CDS Spread during 2003-2016 Using Different Fixed Effects

	(1) EU	(2) EU	(3) Eurozone	(4) Eurozone	(5) OECD	(6) OECD
L.Equity Ratio	-0.14*	-0.11*	-0.15*	-0.11*	-0.20**	-0.25*
	(0.07)	(0.06)	(0.07)	(0.06)	(0.08)	(0.13)
L.Loan Impairment Ratio		0.13		0.14		0.16**
		(0.11)		(0.12)		(0.08)
L.GDP growth rate		-0.24***		-0.28***		-0.14***
		(0.05)		(0.06)		(0.05)
Observations	1,343	1,339	997	993	3,001	2,864
Number of Banks	50	50	38	38	107	103
Adjusted R^2	0.861	0.863	0.856	0.859	0.821	0.828
Within R^2	0.012	0.031	0.012	0.032	0.046	0.059
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Country*Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes

Bank-level clustered standard errors in parentheses

Data sources: Thomson Reuters EIKON, Bankscope quarterly data, OECD

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: The table shows the results from regressing 5-year CDS spreads on banks' equity ratios, controlling for loan impairment charge to gross loans ratios, and real GDP growth rate. Bank fixed effects and country*year fixed effects are included in all regressions. Quarterly data are used and all variables are in decimal places. Lagged explanatory variables are used. The sample is divided into different subgroups according to regions.

Table 19: Direct Relationship between CDS Spread and Concentration Measures in EU Countries

	(1) EU 2003-2016	(2) EU 2003-2011	(3) EU 2011-2016	(4) EU 2003-2016	(5) EU 2003-2011	(6) EU 2011-2016
L.HHI (Bankscope)	-0.06	-0.03	-0.30**			
	(0.07)	(0.10)	(0.12)			
L.Equity Ratio	-0.06	-0.36*	0.03	-0.07	-0.37*	-0.01
	(0.06)	(0.19)	(0.08)	(0.06)	(0.19)	(0.08)
L.Loan Impairment Ratio	0.44*	1.12***	0.15	0.47*	1.11***	0.14
	(0.26)	(0.35)	(0.13)	(0.26)	(0.35)	(0.14)
L.GDP growth rate	-0.29**	-0.30**	-0.27***	-0.30***	-0.30**	-0.31***
	(0.11)	(0.15)	(0.09)	(0.11)	(0.14)	(0.09)
L.5-bank ratio (Bankscope)				-0.06***	-0.04**	-0.11**
				(0.02)	(0.02)	(0.04)
Observations	621	336	350	621	336	350
Number of Banks	74	65	74	74	65	74
Adjusted R^2	0.675	0.605	0.849	0.682	0.608	0.845
Within R^2	0.145	0.252	0.210	0.162	0.257	0.185
Bank Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes

Bank-level clustered standard errors in parentheses

Data sources: Thomson Reuters EIKON, Bankscope annual data, World Bank

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: The table shows the results from regressing 5-year CDS spreads on concentration index HHI or 5-bank concentration ratio, controlling for banks' equity ratios, loan impairment charge to gross loans ratios, and real GDP growth rate and including bank, country and year fixed effects. Annual data are used and all variables are in decimals. Lagged explanatory variables are used. The sample consists of EU banks and is divided into different sub-samples based on time periods.

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