Competition, Stability, and Efficiency in the Banking Industry *

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Abstract

We provide a tractable dynamic model of the banking industry where (1) an intensification of competition increases market measures of efficiency and fragility of banks but not necessarily social measures of efficiency; (2) economies can avoid the fragility costs of competition by enhancing bank governance and tightening leverage requirements; and (3) bank competition materially shapes risk taking and the monetary transmission mechanism. Using detailed data on U.S. banks, we find statistical evidence supportive of the model predictions. In a series of experiments, we show how our simple model can be used to make predictions about the impact of too-big-to-fail, regulatory arbitrage, the impact of changes in financial technology, and contagion/runs on risk taking and competition.

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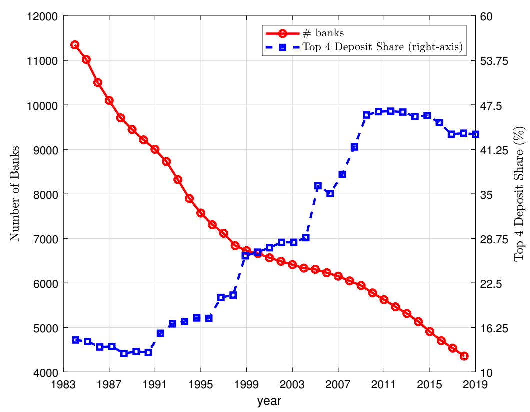
1 Introduction

Policymakers and researchers often stress that there is a tradeoff between competition and stability in the banking industry.[1] They emphasize that although competition boosts market efficiency, it reduces banking system stability by squeezing profits, lowering bank valuations, and encouraging bankers to make riskier investments because they have less to lose. While this *competition-fragility* perspective is not universally accepted[2], it implies that policymakers must make decisions about: (1) the degree of competition via anti-trust policy that appropriately balances the efficiency benefits and the fragility costs of competition, and (2) the use of other supervisory, regulatory, and monetary policies to mitigate the fragility repercussions of competition. While concentration is an imperfect measure of competition (something our empirical analysis attempts to account for), the fact that the number of commercial banks in the U.S. has fallen dramatically while the deposit share of the top 4 banks has tripled as documented in Figure 1 suggests that these issues are becoming ever more important.

Figure 1: U.S. Bank Numbers and Concentration



Note: Number of Banks refers to the number of bank holding companies. Top 4 Deposit share refers to the share of total deposits in the hands of the top 10 banks in the deposit distribution.

Our paper contributes to the literature on competition and stability in several ways.[3]

[1] In discussing the Dodd-Frank Act, Federal Reserve Governor Tarullo [63] argued in 2012 that, "... the primary aim of those 849 pages can fairly be read as a reorientation of financial regulation towards safeguarding 'financial stability' " ... and explains how the act encourages the Federal Reserve to consider financial stability, not just competition and efficiency, in making decisions about proposed bank mergers and acquisitions.

[2] The alternative *competition-stability* view stresses that more competitive banking systems are efficient *and* more stable. This can potentially arise for several reasons. Competition might spur improvements in the screening of potential borrowers, the governance of funded projects, and the management of bank risk. In addition, efficiency-boosting competition tends to lower interest rates that banks charge to firms and these lower rates can reduce firm bankruptcies and enhance bank stability.

[3] Vives [66] provides a comprehensive review of this literature.

First, we build on earlier theoretical papers on competition and stability (such as Allen and Gale [6], Boyd and DeNicolo [17], and Martinez-Miera and Repullo [55]) by: (a) endogenizing bank market structure so that banks enter and exit in the long-run depending on expected profits, (b) incorporating policy tools like leverage requirements and monetary policy effects on external funding into our dynamic model of competition and stability, and (c) allowing for agency frictions between bank owners and managers.[4] Our model provides a tractable (3 equations in 3 unknowns) laboratory for assessing the role that government policy (both regulatory and monetary) has in affecting long run bank market structure and conversely, how bank market structure may affect government policy objectives. Much of the tractability follows from abstracting from bank level heterogeneity associated with a richer stochastic structure found in the imperfect competition models of Corbae and D'Erasmo [24], [26], [27], Egan, Hortascu, and Matvos [35], and Wang et. al. [65].

Second, we take our simple model to U.S. data. Along this dimension, we first calibrate the model and use it to make predictions about how government policies affect competition and stability. Then, we evaluate whether the model's predictions are broadly consistent with the data using regression analyses that builds on the work of Jiang, Levine, and Lin ([49], [50], [51], hereafter JLL). Our empirical work finds support for the *competition-fragility* view. These findings highlight the value of research that helps policymakers choose policies that maximize the efficiency benefits, while minimizing the fragility costs, of competition. This paper is an attempt to help bridge that gap.

Dynamics and agency conflicts, modeled along the lines of Acharya and Thakor [1] where an executive decision maker may be more myopic than shareholders, provide another rationale for policy intervention. Specifically, with respect to improving bank governance, we mean regulatory supervision that either directly or indirectly encourages bank executives to focus more on the long-run value of the bank and less on shorter-run concerns, such as inducing a temporary surge in stock prices that triggers large executive bonuses. To enhance bank governance, policy analysts have proposed, inter alia, regulatory policies that (a) encourage the selection of boards of directors at banks that reflect the long-term interests of shareholders and not the shorter term interests of executives, (b) foster the adoption of executive compensation schemes that foster sound executive incentives, including the potential use of executive "claw back' provisions, and (c) compel the decision makers in banks, which includes bank executives and influential owners, to have material "skin-in-the-game", so that those determining bank risk have a sufficient proportion of their personal wealth exposed to those risks.

In this paper we model governance regulation and supervision as a policy that brings the discount factor of bank managers closer to that of its shareholders. Our model and empirical findings suggest that policymakers can mitigate the fragility repercussions of lowering barriers to competition by enhancing bank governance and tightening leverage requirements with negligible impact on bank profitability and lending. Our findings are consistent with those of Hirtle and Kovner [46] who state (p.45) "Through a variety of lenses, these papers examine how supervision affects the risk-taking, lending, and profitability of supervised banks. The

[4] Other related papers examining competition and stability include Benchimol and Bozou [14], Hellmann, Murdock, and Stiglitz [44] and Perrotti and Suarez [57].

papers generally find that more intensive supervision results in reduced risk-taking. This raises questions as to whether the risk-reducing impact of supervision comes at the cost of reduced lending or lower profits. If this trade-off exists, is it socially optimal? Some papers find that more intense supervision results in reduced credit supply, while others find that supervision reduces risk without significantly reducing lending. Most papers that examine the question find that supervision has a neutral to positive impact on profitability." Moreover, we show that policies which improve bank governance boost banking system efficiency (lowering measured interest margins and lowering risk taking closer to that chosen by the social planner).

With respect to leverage requirements, our model is consistent with reduced risk taking from a tighter constraint inducing an increase in the amount of personal wealth that owners have at risk incentivizes them to constrain excessive risk taking. Interestingly, we find an important interaction effect; tighter leverage requirements has a bigger risk-reducing effect in well governed banks. Thus, our framework, as Hirtle and Kovner [46] state (p. 51) "...has the potential to provide insight into important questions about the design and implementation of bank supervision, including how supervision should interact with regulation..."

With respect to monetary policy, we provide new findings on how monetary policy, here modeled simply as affecting the costs of external finance (such as borrowing at the fed funds rate), affects bank risk taking and lending both in the short and long run across market structures. Only recently, have economists considered the interaction between monetary policy and market structure. For instance, Dreschler, et. al. [34] state (p.1819) "Consistent with the market power mechanism, deposit spreads increase more and deposits flow out more in concentrated markets." We find that monetary policy may have non-monotonic short run effects on lending and risk taking across different levels of banking concentration. While our model predicts that lending may fall more in more concentrated banking markets unless banks are leverage constrained, we do not find that deposit spreads increase more in concentrated markets which is in line with Begenau and Stafford [13]. Our results on the bank lending channel are also related to work by Kashyap and Stein [53]. As they state (p.407) "...we ask whether the impact of monetary policy on lending behavior is stronger for banks with less liquid balance sheets...It turns out the answer is a resounding 'yes.' Moreover the result is largely driven by smaller banks." In our model, more competitive markets with smaller banks face higher external borrowing costs and are more likely to be leverage constrained. Such banks decrease their lending more in response to a rise in external funding costs via monetary policy. Our model also makes predictions that tighter monetary policy can lead to more concentrated markets in the long run since higher funding costs induce less entry.

The paper is organized as follows. Section 2 provides a tractable dynamic model of an imperfectly competitive banking system that roughly captures some key features of U.S. data. We then use the calibrated model to make predictions about the relation between competition, stability, and efficiency as well as study the impact of supervisory/regulatory/monetary policies in both the short and long run in Section 3. In a series of experiments in subsection 3.3, we show how our simple model can be used to make predictions about the impact of too-big-to-fail, regulatory arbitrage, the impact of changes in financial technology, and contagion/runs on risk taking and competition. Section 4 tests some of these predictions using detailed U.S. data.

2 Model

Our model builds on Allen and Gale [6], Boyd and DeNicolo [17], and Martinez-Miera and Repullo [55] who provide theoretical models of risk taking in imperfectly competitive banking industries. The important differences of our work from theirs is that we add:(i) dynamics, (ii) agency conflicts, (iii) market structure determined by a free entry condition, and (iv) a regulatory and monetary policy objective function (akin to solving a Cournot version of a Ramsey problem). Since one of the objectives of our policymaker is financial stability, she takes into account that her actions affect bank profitability, risk taking, and entry thereby endogenizing long run market structure. This helps avoid a Lucas critique with respect to the invariance of market structure to policy.

2.1 Model Environment

There is a risky technology indexed by $S \in [0, 1]$. For each unit input, the technology yields $A \cdot S$ with probability $p(S)$ and yields 0 otherwise. We think of S as the scale of risk ($S = 0$ is a riskless technology that yields no excess return while $S = 1$ is the riskiest technology which always fails). The parameter A can be thought of as a demand or productivity shifter. The technology exhibits a risk-return tradeoff (i.e., higher return projects are less likely to succeed) since $p'(S) < 0$. We make the following parametric assumption $p(S) = 1 - S^\eta$, where $\eta \geq 1$. We think of η as parameterizing the monitoring technology; a higher η implies better monitoring resulting in less risk. If $Z \geq 0$ units are invested in the technology, then expected output $Y \equiv p(S) \cdot S \cdot A \cdot Z$. The (opportunity) cost of the input is given by the strictly convex function $\widetilde{b} \cdot Z + \widetilde{\gamma} \cdot Z^2$, which assures an interior solution.

In the decentralized version of this economy, there are N banks that Cournot compete for insured deposits. After an initial equity injection, E_i, to finance the fixed entry costs κ of starting bank i, loans are financed by deposits since we assume seasoned equity issuance is sufficiently costly (i.e., for bank i, $L_i = D_i$).[5] The total supply of deposits is given by $Z = \sum_{i=1}^{N} D_i$ with inverse deposit supply function given by $r_D(Z) = b + \gamma Z$. We think of b as parameterizing the liquidity services of deposits (i.e. if negative, households supply funds to banks at possibly dominated interest rates to enjoy their convenience yield) as in Krishnamurthy and Vissing-Jorgenson [54] and Begenau [12]. We think of γ as parameterizing the costs of attracting external funds competing with other banks and non-banks (e.g. more competition from non-banks raise the marginal cost γ of attracting funding). A bank manager chooses the riskiness of the loan portfolio S_i and its scale D_i to maximize the discounted profits of the bank subject to a leverage constraint that $\frac{D_i}{E_i} \leq \lambda$. Limited liability

[5] One can interpret the fixed entry costs κ as covering the initial tangible and intangible capital of the bank. Thus, the bank i balance sheet is given by assets $= L_i + \kappa$ and liabilities $= D_i + E_i$. For purely technical reasons, we assume that for arbitrarily large N, the cost of entry becomes infinity.

implies that if a bank is insolvent, it does not pay its depositors.[6] We assume that there is an additional cost α to obtaining external funds that is controlled by monetary authorities (which may be interpreted as a Fed Funds rate). The manager discounts cash flows at rate β. Shareholders with linear preferences and discount factor δ make an initial equity injection to cover the entry cost (i.e., $E_i = \kappa$). The possibility of agency conflicts between the manager and equity holders is captured by $\delta \geq \beta$. We assume a large number of managers, so they take compensation as given. Managers receive a constant fraction f of the earnings of the bank while equity holders receive a fraction $1 - f$. Static preferences of the manager are given by $u(c_M) = \psi_M c_M$ while preferences of equity holders are given by $u(c_E) = \psi_E c_E$. To keep notation simple, we let $\psi_M = f^{-1}$ and $\psi_E = (1 - f)^{-1}$.

2.2 Planner's problem

To obtain the "socially efficient" level of risk taking for our model economy, we first solve the planner's problem in a frictionless economy. The planner chooses the level of risk S and the amount of investment Z to maximize expected output. The planner's problem is given by

$$\max_{S,Z} \mathcal{O} = p(S) \cdot A \cdot S \cdot Z - (\widetilde{b} \cdot Z + \widetilde{\gamma} \cdot Z^2) \tag{1}$$

An interior solution to (1) is given by

$$S^* = \left(\frac{1}{1+\eta}\right)^{\frac{1}{\eta}}, \; Z^* = \frac{A \cdot \eta}{2 \cdot (1+\eta) \cdot \widetilde{\gamma}} \left(\frac{1}{1+\eta}\right)^{\frac{1}{\eta}} - \frac{\widetilde{b}}{2\widetilde{\gamma}}. \tag{2}$$

At the allocation in (2), we have

$$p(S^*) = \frac{\eta}{1+\eta}$$

so that the only parameter which affects the planner's choice of risk taking is η.

Henceforth, we will term a "socially efficient" allocation of risk and investment the (S^*, Z^*) chosen by a social planner in a frictionless economy solving problem (1). This may be in contrast to "market efficiency" measures like interest margins.

2.3 Decentralized Cournot Equilibrium

Here we solve for a Cournot equilibrium in a decentralized banking industry with limited liability and agency frictions. Given such frictions, there is a role for policy to mitigate these frictions and bring the decentralized allocation closer to the "socially efficient" levels of risk and investment chosen by the social planner in the previous section. The literature

[6] Here, as in the Allen and Gale [6] and Boyd and DeNicolo [17] market environments, the industry-wide portfolio either succeeds or fails for simplicity (i.e. individual banks success and failure are perfectly correlated so there are only normal times and crises). We do this for two reasons. First, it maintains consistency with the planner's problem where there are not individual units. Second, idiosyncratic shocks to a finite number of bank portfolios generates an increasing number of aggregate states complicating the analysis. Martinez-Miera and Repullo [55] consider more general stochastic processes.

on optimal linear taxation with commitment has termed the choice of a given set of policy tools in a decentralized economy a "Ramsey equilibrium". In particular, we will solve for a symmetric Markov Perfect Cournot Equilibrium where

a. Taking government policy and the current number N of incumbent banks as given, in each period the manager of incumbent bank i chooses the scale S_i of risk taking and deposits D_i to maximize the present discounted value of profits taking into account they must Cournot compete with the other $N-1$ incumbent banks for their deposits at rate $r_D(Z)$.

b. After incumbent bank exit has occurred, shareholders can make an initial equity injection E_i to pay for the entry cost κ to start new bank i.

c. The regulatory budget constraint must be satisfied in expectation (i.e.,external funds F must cover deposit insurance on failing banks).[7]

d. The policymaker commits to a choice of policy parameters $(\kappa, \beta, \alpha, \lambda)$ to minimize the weighted distance between the decentralized level of risk taking from the planner's level as well as deviations of the decentralized level of expected output from the planner's level given a symmetric Cournot equilibrium.

Note we will call a solution to (a) and (c) a "short-run" Cournot equilibrium (i.e., N is taken as given in the short run). We will call (a), (b), and (c) a "long-run" Cournot Equilibrium. Finally we call a solution to (a)-(d) a Ramsey equilibrium. For simplicity, our paper focuses on stationary symmetric equilibria.

Also, note that in the model, entry costs (κ) and the number of banks (N) are always negatively correlated: lower entry costs spur entry, and the number of banks increases while competition intensifies as the market becomes more contestable. A richer model, however, could allow for a different form of entry costs. For example, banks within this local economy might be protected from competition by barriers that limit banks from other economies from purchasing banks within this locale. These barriers protect incumbent banks from competition. In this case, lowering the costs to foreign banks from buying, and potentially merging local banks, will make the local market more contestable and competitive. The number of banks operating in the local economy, however, might fall even as competition intensifies. We address this below when we turn to the U.S. data.

2.3.1 Bank Problem

We begin by stating condition (a) in our environment (since N is taken as given to an incumbent bank). Assuming limited liability, incumbent bank i's static profit function is given by[8]

$$\pi_i(S_i, D_i; N) = p(S_i)\left[A \cdot S_i - (r_D(Z) + \alpha)\right] D_i. \tag{3}$$

[7] An earlier version of the paper included a tax that solvent banks have to pay to fund deposit insurance. This simply can be subsumed in α without loss of generality.

[8] It is evident from (1) and (3) that if $b = \frac{\widetilde{b}}{p(S^*)}$, $\gamma = \frac{\widetilde{\gamma}}{p(S^*)}$ and $\alpha = 0$, then the aggregate costs of funds in a symmetric decentralized equilibrium is the same as the planner's cost.

Since an incumbent manager maximizes the present value of the solvent bank at discount rate β, the dynamic problem of bank i is given by[9]

$$V_i\left(N\right) = \max_{S_i, D_i} \pi_i(S_i, D_i; N) + \beta p(S_i) V_i(N') \tag{4}$$

subject to

$$\frac{D_i}{E_i} \leq \lambda \tag{5}$$

where N' denotes the number of banks next period.

At the time the (S_i, D_i) choice is taken, since entry has already occurred and seasoned equity issuance is prohibitively expensive then $E_i = \kappa$ and N is taken as given. In that case, attaching a multiplier μ to constraint (5), the first order conditions from problem (4)-(5) are given by[10]

$$S_i : p(S_i) \cdot A \cdot D_i + p'(S_i) \cdot R_i \cdot D_i + p'(S_i) \cdot \beta \cdot V_i(N') = 0, \tag{6}$$

$$D_i : p(S_i) \cdot R_i - p(S_i) \cdot r'_D\left(Z\right) \cdot D_i - \frac{\mu_i}{\kappa} = 0. \tag{7}$$

where $R_i \equiv (A \cdot S_i - (r_D(Z) + \alpha))$ denotes the interest margin. The first benefit term in (6) is the expected revenue from taking a more risky scale in successful states while the second two cost terms (since $p'(S_i) < 0$) are the decrease in the likelihood of success both on current profits and the possible loss of future charter value. The first benefit term in (7) is the interest margin on all existing deposits while the second and third cost terms are the loss in revenue from having to pay more to attract deposit funding as well as tightening the leverage constraint, respectively.

For a given number N of incumbent banks and fixed value of future operations $V(N')$, imposing symmetry of banks' strategies in the first order conditions from (6)-(7), so that $S_i = S^C$, $D_i = \frac{Z^C}{N}$ and $Z_{-1} = \frac{(N-1)}{N} Z^C$, provides two equations in two unknowns (S^C, Z^C) in a short-run symmetric Cournot equilibrium.[11]

Recognizing a given manager solves problem (4)-(5) to generate a sequence of cash flows $\pi_i^C(N) \equiv \pi_i(S^C, D^C; N)$ each period, condition (b) in our definition of equilibrium requires that shareholders with discount rate δ will inject equity to fund bank i entry provided

$$E_i\left(N\right) \equiv \frac{\pi_i^C(N)}{1 - \delta p(S^C)} \geq \kappa. \tag{8}$$

This free entry condition (i.e., (8) with equality) pins down N^C in a symmetric equilibrium.

[9] The static reward in equation (4) follows since the manager's preferences are given by $u(c_M) = \frac{c_M}{f}$ and $c_M = f \cdot \pi$.

[10] As in many dynamic IO models (see Doraszelski and Pakes [33]), we follow a traditional static-dynamic breakdown whereby a price or quantity decision affects static profitability but not the dynamics of the entire industry.

[11] When solving for a symmetric equilibrium, we check that any given bank can choose a one-shot deviation from the symmetric strategy.

Note that in a symmetric equilibrium (4) and (8) with equality implies

$$V(N^C) = \frac{\left[1 - \delta p(S^C)\right]}{\left[1 - \beta p(S^C)\right]} \cdot E(N^C), \tag{9}$$

so that there is a wedge

$$w(S^C) \equiv \frac{\left[1 - \delta p(S^C)\right]}{\left[1 - \beta p(S^C)\right]} \tag{10}$$

between managerial value of the firm and shareholder value. In particular, when managers are myopic relative to shareholders (i.e $\beta < \delta$), the wedge $w(S^C) < 1$ and shareholders value the firm more than the manager (i.e., $V(N^C) < E(N^C)$).

There are policy-relevant advantages to modeling separately the incentives of executives (β), the incentives of shareholders (δ), and the wedge between the two (w). First, as stressed above, executive compensation schemes, claw back provisions, etc. can all influence the degree of executive myopia. Our model then shows how executive myopia can influence bank risk, lending, and the influence of other policies on the economy. Second, limited liability and too-big-to-fail policies can insulate bank owners from the repercussion of failed investments, inducing owners to put less weight on the future downside implications of risky ventures. In turn, our model shows how a reduction in δ tends to increase bank risk taking. Third, many laws and regulations influence the degree to which owners compel executives to act in the best interests of owners. In our model, w reflects the gap between the owners' and executives' weighting of the long-run value of the bank.

These agency conflicts have implications for how leverage affects risk taking. In particular, the two first order conditions (6)-(7) in an equilibrium where the leverage requirement is non-binding can be written

$$p(S_n^C) = -\frac{p'(S_n^C)}{A} \cdot \left[R_n^C + \beta \cdot \frac{E(N_n^C)}{D_n^C} \cdot w(S_n^C)\right], \tag{11}$$

$$R_n^C = \frac{r'_D\left(Z_n^C\right)}{N_n^C} \cdot Z_n^C, \tag{12}$$

where subscript "n" denotes "non-binding". Since $-p'(S_n^C) > 0$, (11) implies that ceteris paribus the probability of success is inversely related to leverage and agency conflicts. Further, (11) shows there is an interaction between leverage and agency. Finally, (11) implies that, ceteris paribus, constraints on the amount of leverage the bank can take on (i.e., leverage requirements) will raise the likelihood of success. Finally, equation (12) says that, for a given Z, the interest margin R is declining in competition $\frac{r'_D(Z)}{N} = \frac{\gamma}{N}$.[12]

[12]In fact, (12) can be simplified to yield

$$N_n^C\left(AS_n^C - \left(\gamma Z_n^C + \alpha + b\right)\right) = \gamma \cdot Z_n^C \iff Z_n^C = \frac{N_n^C\left(A \cdot S_n^C - \alpha - b\right)}{\gamma \cdot (N_n^C + 1)}.$$

In an equilibrium where the leverage requirement is binding, (6) is unchanged but (7) is given by

$$R_b^C = \frac{r'_D\left(Z_b^C\right)}{N_b^C} \cdot Z_b^C + \frac{\mu}{p(S_b^C)\kappa}, \tag{13}$$

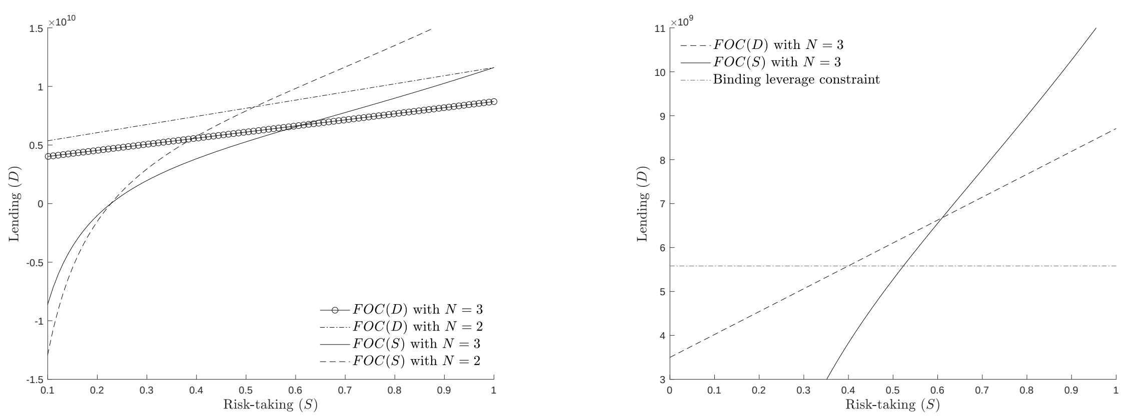
where the subscript "b" denotes "binding". Since the multiplier on the leverage constraint $\mu > 0$ when binding, (13) implies that tighter leverage constraints requires higher interest margins (in the short run when N is fixed) relative to the unconstrained equilibrium. Further, since the constraint binds, we know $Z_b^C = N_b^C \cdot \lambda \cdot \kappa$ which when substituted into (6) yields

$$p(S_b^C) = -\frac{p'(S_b^C)}{p(S_b^C)} \cdot \frac{w(S_b^C)}{A\lambda}. \tag{14}$$

As in (11) for the non-binding case, (14) shows that ceteris paribus a tight leverage requirement can increase the probability of success while agency conflicts decrease the probability of success. Note, however, that (14) implies that the probability of failure is independent of market structure N when leverage requirements are binding.

We illustrate the two first order conditions (6) and (7) in a symmetric equilibrium, which are functions of market structure N, graphically in the next series of figures. In particular, Figure 2a provides the two first order conditions for two possible market structures (drawn for our calibrated parameter values) when the leverage constraint is non-binding (i.e. $\mu = 0$). As evident in Figure 2a the level of risk-taking S is higher and individual bank lending $D = L$ is lower in our benchmark $N = 3$ market structure relative to a less competitive $N = 2$ market structure.

Figure 2: Comparative statics



(a) Risk-Taking and Lending FOCs Across Market Structure

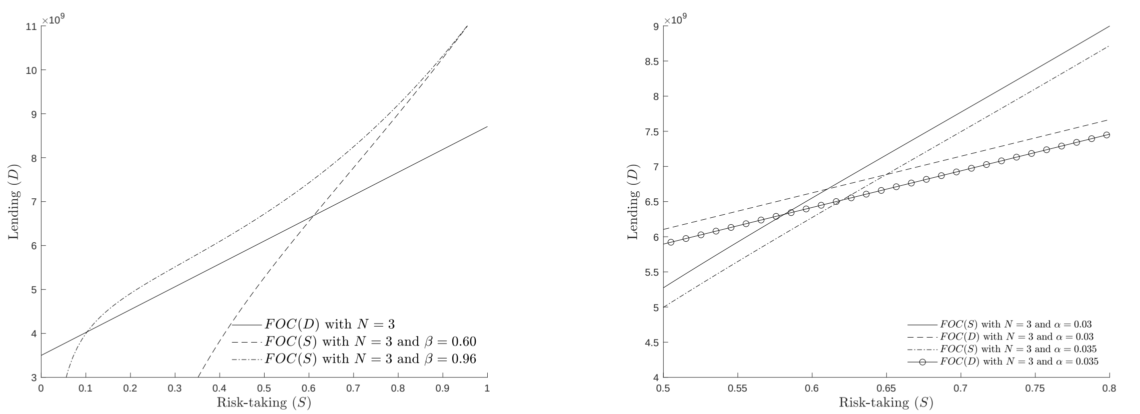
(b) Leverage Unconstrained versus Constrained FOCs

Note: In terms of the first panel, FOC(S)-N and FOC(D)-N denote first order conditions for S and D for a given market structure N. Regarding the second panel, FOC(S) and FOC(D) denote first order conditions for S and D for $N = 3$, and binding leverage constraint - $\lambda = 13$ pins down D.

In Figure 2b, we illustrate the effect of leverage constraints (i.e. differences between the unconstrained and constrained cases) when $N = 3$. In particular, when λ is sufficiently high (as in our benchmark calibration where $\lambda = 18.20$), then the leverage constraint is nonbinding (so $\mu = 0$) and the first order conditions are the same as in Figure 2a. However, when we tighten the leverage constraint to $\lambda = 13$ the first order condition for deposit choice (7) binds, pinning down D independent of S. It is evident from the graph that tighter leverage requirements lowers both risk taking and lending in the short run.

In Figure 3a, we illustrate how agency conflicts affect risk taking and lending when $N = 3$. In particular, in our benchmark managers are more myopic than equityholders (i.e. $\beta = 0.60$ for managers while $\delta = 0.96$ for equityholders). Recall that the agency wedge $w(S)$ only appears in the first order condition for risk taking (11). Thus, as we vary β in this figure, the first order condition for deposit taking does not vary. Figure 3a makes clear that mitigating agency conflicts reduces lending and risk taking in the short run.

Figure 3: Comparative statics



(a) Agency Conflicts Effects on FOCs

(b) Contractionary Policy Effects on FOCs

Note: Regarding Panel a, FOC(S)-beta and FOC(D) denote first order conditions for S and D with $N = 3$ across $\beta = 0.60$ benchmark versus $\beta = \delta = 0.96$. In terms of Panel b, FOC(S)-α and FOC(D)-α denote first-order conditions for S and D with $N = 3$ across $\alpha = 0.03$ benchmark versus $\alpha = 0.035$.

Finally, in Figure 3b, we illustrate how contractionary policy (exogenous increases in the marginal cost of funding to banks captured by an increase in α affect risk taking and lending when $N = 3$. In particular, we raise α from 0.03 in our benchmark to 0.035 (i.e. a 50 basis point rise in funding costs). Figure 3b makes clear that as contractionary monetary policy raises the cost of funding loans, lending drops but risk taking rises in the short run.

2.3.2 Government Budget Constraint

Condition (c) requires that the expected outflows at insolvent banks from the deposit insurance fund be funded by taxes F satisfying:

$$F = (1 - p(S^C)) \cdot r_D(Z^C) \cdot Z^C. \tag{15}$$

2.3.3 Policymakers Problem

Condition (d) endogenizes government policy with commitment as a variant of a "Ramsey Equilibrium". In particular, the policymaker chooses policy parameters $\Theta = (\kappa, \beta, \lambda, \alpha)$ - interpreted as anti-trust, supervision, regulatory, and monetary - to minimize the weighted distance between the decentralized level of risk taking level (with weight $1-\phi$) as well as deviations in expected output (with weight ϕ) from their targets (which can be what the planner chooses in (1)). The policymaker's problem is given by

$$\min_{\Theta}(1-\phi) \cdot \left|S^C - S^*\right| + \phi \cdot \left|Y^C - Y^*\right| \tag{16}$$

where $Y = p(S) \cdot A \cdot S \cdot Z$.

2.3.4 Definition of Equilibrium

The fact that there are no endogenous state variables in the dynamic programming problem of the bank simplifies our analysis tremendously and means that effectively we have a sequence of equations defining an equilibrium which are not linked through time.

Definition 1. *Taking policy parameters Θ as given, a <u>symmetric recursive Cournot equilibrum</u> is 4 equations in 4 unknowns $(S^C_\Theta, D^C_\Theta, N^C_\Theta, F^C_\Theta)$ such that:*

- *First order condition (6) with respect to risk taking S (determines loan portfolio success probability $p(S^C_\Theta)$).*
- *First order condition (7) with respect to deposit funding D (determines aggregate lending $Z^C_\Theta = N^C_\Theta \cdot D^C_\Theta$).*
- *Free entry condition (8) N (determines bank market concentration $\frac{1}{N^C_\Theta}$).*
- *Government Budget Balance (15) F^C_Θ (determines expected government tax outlays).*

Next, our variant of a "Ramsey equilibrium" is

Definition 2. *For a given set of weights ϕ, a <u>Ramsey equilibrium</u> is defined by the government choosing among Θ to minimize its objective (16) where every Θ is consistent with a symmetric recursive Cournot equilibrium as in Definition 1.*

In order to conceptualize our policy experiments, we split the problem into two parts: a "short" and "long" run response to an unanticipated permanent policy change. Specifically, we define "short" and "long" run in the following way:

- Short Run: Taking market structure N as given by our benchmark calibration, how do scale of risk taking S and aggregate lending Z change with a change in the policy parameter Θ recognizing that with some probability (i.e. an expected duration) we will enter a new long run equilibrium consistent with free entry at the new parameter values?

- Long Run: Market structure N changes since policy affects the charter value of the bank (and hence the entry condition consistent with the original benchmark entry costs κ).

Maintaining a fixed N in the presence of a change in a policy parameter induces the bank to choose a short run level of risk taking and lending that induces new static and long run profits conditional on the fixed N. That is, for a fixed N, interest margins R, static profits π, and market value of the bank E react to the new policy. The "long-run" equilibrium allows the industry structure N to change (e.g. via entry and exit) in response to the policy intervention.

For simplicity, we implement the "transition" between the original steady state equilibrium and the new long run steady state equilibrium associated with the policy change in the following way. In particular, we assume the market structure N_Θ remains at the original benchmark level associated with policy Θ until with probability ζ the market structure changes to the new, post-policy Θ' steady state value of $N_{\Theta'}$ consistent with entry given the effect of the policy change on the profitability of banks. For simplicity, we will simply denote $N_\Theta \equiv N$ and $N_{\Theta'} \equiv N'$.

The timing behind this implementation is given by:

1. Start the period with industry structure N.
2. Given N, the policy change induces static profits $\pi_{\Theta'}(S_{\Theta'}, D_{\Theta'}; N)$ given in equation (3) inducing a post-policy change in the market value of the bank $\frac{\pi_{\Theta'}(S_{\Theta'}, D_{\Theta'};N)}{1-\delta p(S_{\Theta'})}$.
3. Possible transition to N' consistent with the new entry condition in equation (8) at rate ζ. If transit to N', stay there forever.

This implies the value function (formerly in (4)) following the policy change Θ' is now given by

$$V_{\Theta'}(N) = \max_{S,D} \pi_{\Theta'}(N) + \beta p(S_{\Theta'}) \left[(1-\zeta)V_{\Theta'}(N) + \zeta V_{\Theta'}(N')\right] \tag{17}$$

subject to the leverage constraint (5). In the standard case of a non-binding leverage constraint, the transition has no direct effect on the first order condition for deposits (7), but does affect the first order condition for risk taking (6). In particular, it can now be written

$$p(S_{\Theta'}) \cdot A \cdot D_{\Theta'} = -p'(S_{\Theta'}) \cdot \left\{R_{\Theta'} \cdot D_{\Theta'} + \beta \cdot \left[V_{\Theta'}(N) + \zeta\left(V_{\Theta'}(N') - V_{\Theta'}(N)\right)\right]\right\} \tag{18}$$

Equation (18) is identical to (6) when $\zeta = 0$, but the cost of risk taking rises or falls depending on whether or not the long run effect of the policy change on charter value exceeds the short run effect (i.e. whether $V_{\Theta'}(N') \lesseqgtr V_{\Theta'}(N)$). The matlab code to run the model is described in Appendix B and can be found on the authors' websites.

2.4 Calibration

Next we calibrate the model to U.S. data consistent with the sample period of our empirical analysis in Section 4. The model has two sets of parameters. One set are those associated with technologies and preferences $(A, b, \gamma, \eta, \delta)$.[13] The second set are those associated with government policy $(\kappa, \beta, \lambda, \alpha)$.

The benchmark model we calibrate assumes (i) there are agency conflicts and (ii) leverage requirements are non-binding. Taking a model period to be one year, we set $\delta = 0.96$. As discussed (p.2) in [64], the Office of the Comptroller of the Currency's capital regulation for the period of our sample was a relatively simple leverage ratio of capital divided by assets which set a minimum of 5.5 percent implying $\lambda = 18.20$. During this period, inflation was on average approximately 4 percent (from FRED), the real fed funds rate was approximately 3 percent and the real deposit rate was approximately 1 percent (both from Dreschler, et. al. [34]). Hence we set as targets the real return on deposits r_D to 1 percent and the real return on fed funds α to 3 percent implying an average spread (denoted Sp) of 2 percent.

Table 1: Data (from JLL (2018) and Benchmark Model Moments

	Data	Model
Concentration	0.330	0.333
ROA	0.04	0.025
cv(ROA)	0.203	0.019
D/E	14.830	15.56
log(Deposits)	22.466	22.62
Real deposit rate	0.01	0.006

Table 2: Benchmark Parameters

	values
δ	0.970
λ	18.20
α	0.030
β	0.600
$\mathbf{A}$	0.125
η	2.000
b	-0.114
γ	6×10^{-12}
κ^*	429.25

Left Table: * In millions. Right Table: Parameters above the line are chosen outside the model. Parameters below are chosen inside the model.

The remaining parameters are chosen to match summary statistic data in Table 2 of Jiang, Levine, and Liang [50] along with new calculations. In particular, mean bank concentration of 0.33 implies we target $N = 3$.[14] We define the net return on assets (ROA) to be net interest income over total interest bearing assets. We find a mean level of 0.04 implies we target $\frac{\pi}{D} = 0.04$. The mean coefficient of variation on interest bearing assets is constructed from the volatility of assets implied from the Merton [56] model normalized by the gross return on assets to give a scale-free measure of bank profit volatility which is 0.203. The model moment we use to match this measure is the standard deviation of loan returns normalized by the gross return on assets. Mean leverage of 14.83 in the last year of our sample implies we target $\frac{D}{E} = 14.83$. Mean log of total deposits of 22.46 implies we target $log(D) = 22.46$.[15] The parameter b is identified by matching the data on interest rates. We interpret $b < 0$ as evidence for a convenience yield. Table 1 presents the model generated moments relative to the data while Table 2 presents the parameters (those chosen outside the model on top and those chosen within the model below). While the model underestimates variation in the return on assets, it does well on other moments.

[13]Since our observations are from the decentralized economy, we calibrate b and γ to match market data noting the one-to-one mapping to the planner technology parameters $\widetilde{b} = b \cdot p(S^*)$ and $\widetilde{\gamma} = \gamma \cdot p(S^*)$.

[14]Concentration is measured as the summation of squared bank holding company asset shares (i.e., the Herfindahl index).

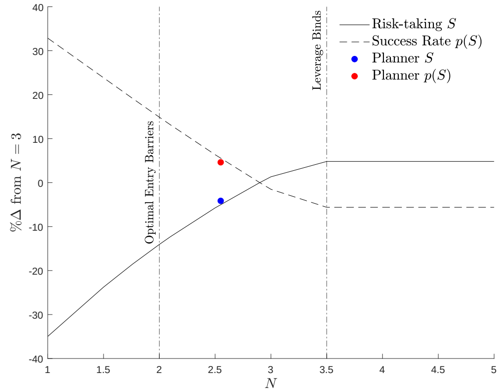
[15]It can be shown that γ is uniquely identified by this moment.

3 Counterfactuals

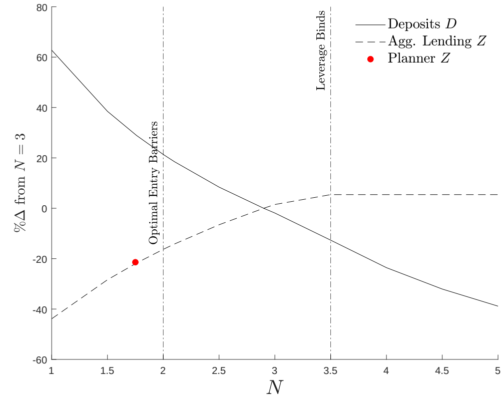
3.1 Model Predictions about Competition, Stability, and Efficiency

Having chosen model parameters to roughly match key U.S. banking data moments, we now use the calibrated model (what we call the "benchmark" where $N = 3$) to make predictions about competition, stability, and efficiency. In the benchmark model, individual banks make noncooperative decisions in a decentralized environment with limited liability and agency conflicts (as opposed to a social planner selecting optimal levels of risk and lending in a frictionless environment). Figure 4 depicts percentage deviations of risk taking (S) and aggregate lending (Z) from the benchmark vis-a-vis levels (a) chosen by the social planner, (b) that arise in a less competitive economy (where $N = 1$), (c) that arise in a more competitive economy (where $N = 5$). Furthermore, it shows the percentage deviations of risk taking and aggregate lending that arise when a policy maker optimally chooses entry barriers (κ) to minimize equally-weighted ($\phi = 0.5$) deviations of bank risk taking and output from the social planner's efficient levels.

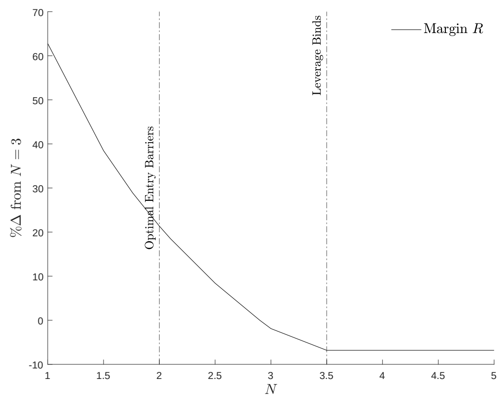
Figure 4: Competition, Stability, and Efficiency



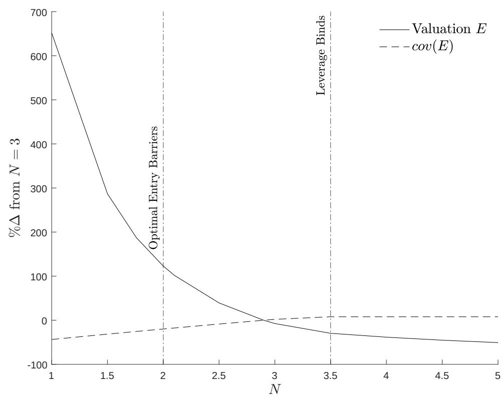
(a) Stability



(b) Lending



(c) Market Efficiency



(d) Market Value

Note: Percent deviations from the benchmark ($N = 3$): Less Competitive ($N = 1$), More Competitive ($N = 5$), Optimal Policy ($N = 2$).

What are the predictions from the changes in market structure depicted in Figure 4 (and presented in more detail in Table A1 in the Appendix)? In these experiments, we choose the level of entry costs κ consistent with a given market structure. For example, κ is lower for the benchmark with $N = 3$ than the κ consistent with the monopoly case where $N = 1$. We find that when we choose an even lower κ consistent with $N = 5$, the equity value of banks in this more competitive environment is sufficiently low that the leverage constraint $D/E \leq \lambda$ binds, illustrated in the Figure. The fact that more competitive environments are likely to result in binding regulatory constraints is consistent with the modeling environment in Begenau [12].

First, there is a positive monotonic relation between competition N and risk taking scale S. Risk taking is substantially lower in the less competitive $N = 1$ economy than the benchmark while it is marginally higher in the $N = 5$ economy, in part because the leverage constraint binds there. This monotonic relation translates into lower probabilities of success in the more competitive economy.

Second, while the social planner takes less risk than the benchmark, despite the agency problems and limited liability, banks in the less competitive $N = 1$ economy actually take less risk than what the social planner would choose. That is, too little competition may generate inefficiently low risk taking as a monopolist bank attempts to guard its charter value. Since the choices of the decentralized bank differ from the social planner's choice, there is a role for a policymaker to intervene.

Third, relative to the social planner, there is "over-investment" (Z) in the benchmark and more competitive economies. Specifically, while there is a positive monotonic relation between competition and aggregate lending Z, a monopolist $N = 1$ bank "underinvests" relative to the social planner's choice while there is "overinvestment" relative to the planning allocation in the $N = 3$ and $N = 5$ economies. Investment depends not only on the number of banks but also the "size" (D) of each bank. Banks are monotonically smaller the higher the degree of compeition.

Fourth, interest margins ($R \equiv A \cdot S - (r_D(Z) + \alpha)$) are monotonically decreasing in the level of competition. Specifically, interest margins are 2.6 basis points higher in the less competitive economy while they are 0.2 basis points lower relative to the benchmark when $N = 5$. Expected static (π) and long run profits ($\kappa = E$) are decreasing in the level of competition, as are valuations of equity. Since equity decreases more than deposits as competition rises, leverage is monotonically increasing in the degree of competition.

Fifth, intermediated output is increasing in the level of competition. Despite this, since risk taking is increasing in competition, expected expenditure to finance failures (F/Y) is also rising. Competition increases the likely payout from the deposit insurance agency.

Finally, the economy is more volatile in competitive environments. The coefficient of variation of both output and equity value are increasing in the degree of competition.

Given that there is excessive risk taking and over-investment in the benchmark, there is room for a policy-maker to adjust entry barriers to help alleviate this inefficiency. As evident from the previous findings, the level of risk taking and aggregate investment undertaken by the social planner lies between that of the monopoly ($N = 1$) and the benchmark ($N = 3$) market structures. To analyze how anti-trust policy makers would choose the optimal entry barriers κ, we need to define "optimal". Here, we have the policy maker choose the level of entry barriers that minimizes deviations from the levels of risk taking and output chosen by the social planner in (1).[16] We give equal weight to deviations from risk taking and output, so that the policymaker chooses κ to solve problem (16) where $\phi = 0.5$. It is clear from Figure 4 and Table A1 that by optimally choosing a higher entry barrier κinduces the "number" of banks to fall to 2, effectively implementing a duopoly market structure. [17] Further, Table A1 makes clear that the optimal policy induces banks to take on much less leverage (nearly 50% lower) than the benchmark. This completes the description of a "Ramsey" equilibrium

[16] A similar type of exercise is undertaken in Benchimol and Bozou [14].

[17] For our benchmark calibration, these results are robust to setting $\phi = 1$, so that the policymaker has the same objective as the social planner. Specifically, N is monotonically decreasing in ϕ with $N = 2.5$ for $\phi = 0$ and $N = 1.75$ at $\phi = 1$.

for our environment.

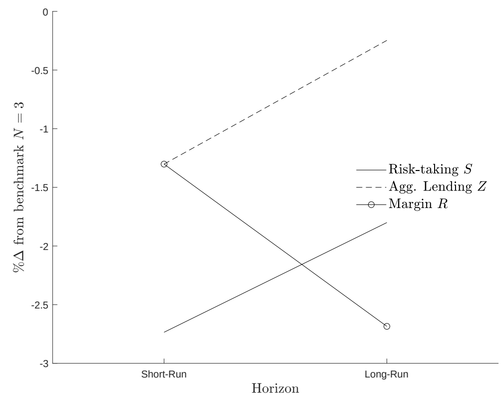
3.2 Model Predictions with Alternative Policy Interventions

We now use the model to make predictions about competition and stability across a set of possible alternative policy interventions. We do so by computing equilibria under the following alternative parameterizations: (a) supervisory policies designed to mitigate agency conflicts (i.e., we increase the manager's discount factor from $\beta = 0.60$ to $\beta = 0.65$ closer to that of the shareholders $\delta = 0.96$), (b) regulatory policy which impose binding leverage constraints (i.e., we drop λ from 18.2 to 4.5, which is a binding constraint relative to the benchmark), and (c) implement contractionary monetary policy (i.e., we increase the marginal cost of funds to $\alpha = 0.035$ from $\alpha = 0.03$). In all cases, we assume $\zeta = 0.05$ so that it takes on average 20 years to transition to the new long run equilibrium associated with the policy change. Our value of ζ is consistent with the roughly 20 year transition in asset market shares between the "steady state" levels of 26% prior to 1991 and 60% after 2009 evident in Figure 1.

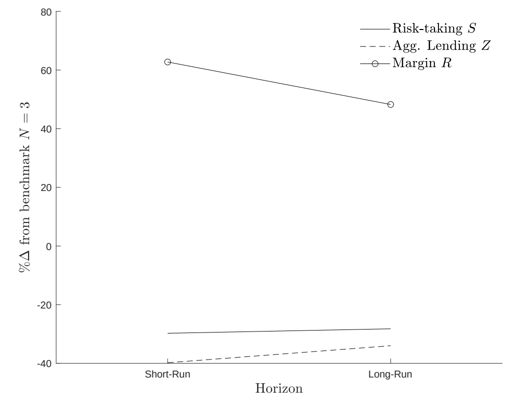
3.2.1 Supervision and Regulatory Policy Counterfactuals

First, we analyze the short and long run impacts of agency conflicts in the left panels of Figure 5 (and columns 1 and 2 of Table A2). In the short run, better governance policies that induce a manager to be less myopic encourage less risk taking resulting in higher success probability. Less myopic managers take on less leverage resulting in lower aggregate lending. Less leverage induces a small drop in deposit interest rates, almost no change interest margins which along with the increase in success probability leads to an increase in short run profits and equity values. Further, lower risk taking leads to a drop in the volatility of bank equity. The decrease in lending outweighs the increase in success probability to generate lower output but also lower variation of output. The higher success probability leads the expected cost of funding bank failures to fall in the short run.

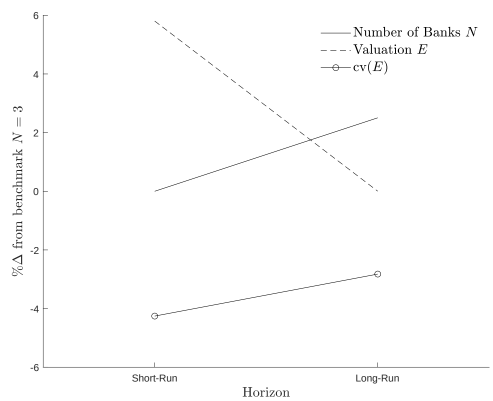
Figure 5: Supervision and Regulatory Policy Counterfactuals



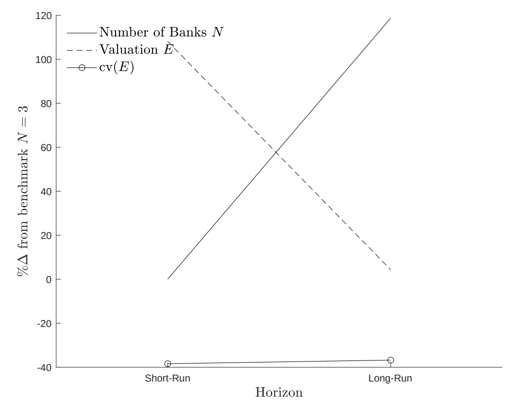
(a) Mitigating Agency



(b) Tightening Leverage



(c) Mitigating Agency



(d) Tightening Leverage

Note: SR vs LR, % deviations from benchmark. Mitigating agency ($\beta = 0.65 < \delta = 0.96$), Tight Leverage ($\lambda = 4.5$).

Given that the governance change leads to higher equity values in the short run (i.e. for a fixed market structure N), it is natural that there will be entry in the long run. The long run impact of mitigating agency conflicts is also illustrated in Figure 5 (and column 2 of Table A2). The rise in entry leads to more competition, which in turn lowers the long run decrease in risk taking and aggregate lending while interest margins fall with more competition. Further, there is no change in output in the long run while there are decreases in its variance, the costs of funding deposit insurance, and importantly the variability of equity.

Second, we analyze the impact of tightening leverage requirements (to a level which is binding relative to the unconstrained benchmark) in the right panels of Figure 5 (and columns 3 and 4 in Table A2). In the short run, tighter leverage requirements lead to less risk taking resulting in a higher success probability. Tighter leverage constraints reduce lending/investment relative to the benchmark and drive the economy toward the risk and lending levels selected by the social planner. With reduced leverage, interest on deposits drop 4.8 basis points and interest margins rise by 2.5 basis points. This leads to a short run rise in profits and equity values. The decrease in aggregate lending leads to a decrease in output, its volatility, expected FDIC costs, and importantly also decreases the volatility of bank equity.

Given that the policy change leads to a rise in equity values in the short run (i.e. for a fixed market structure N) due to an associated drop in funding costs and rise in interest margins, there will be entry in the long run which is also illustrated in Figure 5 (and column 4 of Table A2). The rise in long run profits induces Entry leads to even smaller banks in the long run (i.e. lower D) but the increased number of banks lessens the decrease in aggregate lending $Z = N \cdot D$ relative to the pre-policy benchmark. Thus tightening leverage constraints has the perhaps unintended consequence of a more competitive banking system.

Finally, we emphasize that the same policy change may interact with other features of the economy to magnify the effectiveness of the policy as suggested by Hirtle and Kovnar [46]. For instance, the interaction of tightening leverage (reducing λ) and decreasing agency conflicts (increasing β) might magnify the reduction in risk-taking. Owing to the highly non-linear elasticity of our agency wedge $w(S_n^C)$ with respect to risk-taking S_n^C in (11), leverage and managerial myopia do not generate cross-partials of the same sign everywhere in the parameter space. Denote $S(\lambda, \beta)$ to be the equilibrium risk-taking with leverage constraint λ and manager discount factor β holding all other parameters constant. Columns 5 and 6 of Table A2 computes this counterfactual where both leverage constraints are tightened and agency conflicts are lessened (i.e., setting $\lambda = 4.5$ and $\beta = 0.65$). Under our benchmark calibration, we find that, in the short run, the percentage change in risk-taking from tighter leverage requirements is $\Delta(S; \beta_L = 0.60) = \frac{S(\lambda_L, \beta_L) - S(\lambda_H, \beta_L)}{S(\lambda_H, \beta_L)} = \frac{0.4287 - 0.6103}{0.6103} = -29.7\%$ while in an environment where there is no agency conflict the percentage change in risk-taking induced by the tightening of leverage requirements is $\Delta(S; \beta_H = 0.65) = \frac{S(\lambda_L, \beta_H) - S(\lambda_H, \beta_H)}{S(\lambda_H, \beta_H)} = \frac{0.4167 - 0.5936}{0.5936} = -29.8\%$. Thus we find a 0.1% higher interaction effect when agency conflicts are mitigated than in the baseline case.[18] This finding motivates our empirical analysis in Section 4.4.

3.2.2 Monetary Transmission and Competition

Next we analyze the impact of a policy which increases the marginal cost of funds α by 50 basis points (from 0.03 in the benchmark to 0.035) in the left panel of Figure 6 (and center columns 5 and 6 of Table A3). One way to interpret this is a contractionary monetary policy (i.e., a rise in the Fed Funds rate). In the short run (i.e. with $N = 3$ fixed at the benchmark), a rise in the marginal cost of funds leads banks to take on more risk resulting in a lower success probability. Contractionary monetary policy has the intended consequence of

[18] That is, $\Delta(S; \beta_H = 0.65) - \Delta(S; \beta_L = 0.6) = -0.1$ and since the cross partial $\frac{\partial^2 S}{\partial \beta \partial \lambda}$ is for a rise in λ, we need to take -(-0.1).

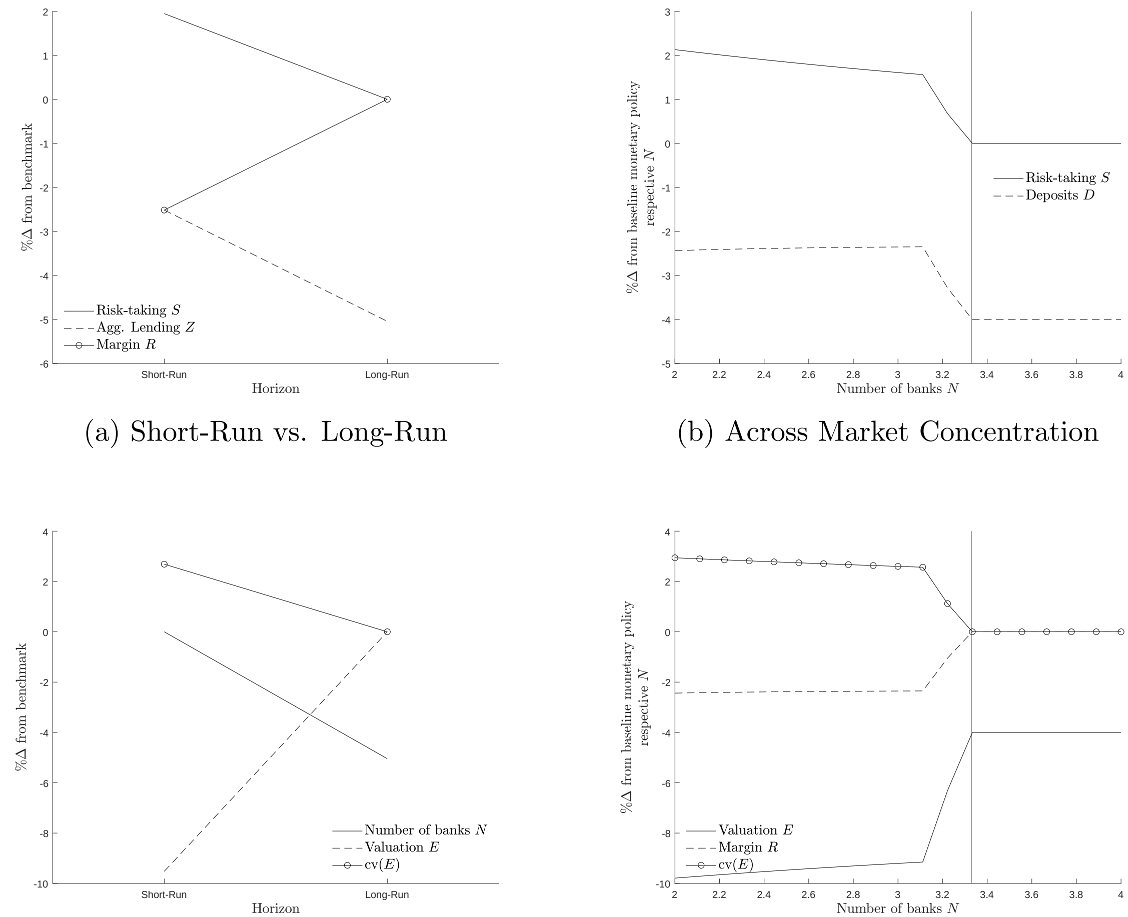
lowering aggregate lending/investment in the short run. The spread $(\alpha - r_D(Z))$ rises with alpha while deposit rates and interest margins fall by 0.3 and 0.1 basis points respectively. The fall in profitability induces lower equity values and despite lower individual bank lending, leverage rises. Importantly, equity volatility rises with contractionary monetary policy. The decrease in aggregate lending leads to lower intermediated output and increased volatility of output as well as increased expected FDIC costs.

Since profitability and equity values fall in short run, the incentive for bank entry also falls thereby leading to less long run competition (i.e. N falls 4%). Falling competition, which ceteris paribus leads banks to take less risk, offsets the short run increase in risk taking so that there is a zero long-run impact on risk taking (relative to the benchmark). This translates to zero long run effect on volatility of equity. Thus, a contractionary monetary policy, for instance, could lead to short run instability but not affect long run stability. Further, the short-run decrease in aggregate lending is magnified in the long-run since there are fewer banks.

As in the previous subsection, we emphasize that the same policy change may interact with other features of the economy to magnify or decrease the effect of policy on risk taking. Specifically, the interaction of contractionary policy (raising α) and increasing competition (increasing N) might actually decrease risk-taking. Denote $S(\alpha, N)$ to be the equilibrium risk-taking at monetary policy α in market structure N holding all other parameters constant. We can use Table A3 to computes this interaction effect where monetary policy is tightened across market structures. Specifically, the difference-in-difference cross partial calculation $\frac{\partial^2 S}{\partial N \partial \alpha}$ is given by $\frac{\partial S}{\partial \alpha}|_{N=3} - \frac{\partial S}{\partial \alpha}|_{N=2} = 1.5\% - 2.0\% = -0.5\%$. Thus the model predicts a negative interaction effect of contractionary policy on risk taking as competition increases. This finding motivates our empirical analysis in Section 4.5.

In summary, the short and long run impacts of contractionary policy on risk taking go in opposite directions so that while there is a short run rise in risk taking and volatility there is no long run effect (i.e. monetary neutrality) on risk taking and the volatility of equity. On the other hand, aggregate lending is decreased through the intensive margin (decreased D) in the short run but magnified through the extensive margin (decreased $N \cdot D$) in the long run leading to greater long run output effects.

Figure 6: Monetary Policy Counterfactuals: Contractionary Monetary Policy



(a) Short-Run vs. Long-Run (b) Across Market Concentration

(c) Short-Run vs. Long-Run (d) Across Market Concentration

Notes: left panel SR vs LR associated with a rise from $\alpha = 0.03$ to $\alpha = 0.035$; right panel SR associated with rise from $\alpha = 0.03$ to $\alpha = 0.035$ for $N = 2$ and $N = 3$ respectively.

In the right panel of Figure 6 (and columns 2, 3, 8, and 9 of Table A3 in the Appendix), we consider the impact of contractionary monetary policy across different market structures. In particular, we ask what is the effect of increasing α by 50 basis points to 0.035 from 0.03 in the benchmark ($N = 3$) market structure versus a less competitive economy ($N = 2$ where leverage constraints do not bind) as well as a more competitive economy ($N = 4$ where leverage constraints bind)? This is relevant for thinking about the monetary transmission mechanism studied in papers such as Kashyap and Stein [53] and Dreschler, et. al. [34]. Both papers effectively conduct difference-in-difference studies of contractionary policy across banks of different degrees of liquidity (i.e. distance from their leverage constraint) in Kashyap and Stein or levels of concentration in Dreschler, et. al.

As one can see from Figure 6 and Table A3, the short run responses in the $N = 2$ economy are of a similar qualitative sign as the $N = 3$ economy discussed above. This is also true for the leverage constrained $N = 4$ economy except that risk taking is unchanged due to the binding constraint. This implies the rise in risk taking and equity volatility in response to a contractionary rise in α falls as the level of competition rises. On the other hand, there is a non-monotonic effect on deposit responses; the drop in lending in response to a contractionary rise in α at first falls and then rises as the level of competition rises eventually leading to a binding leverage constraint. Finally, spreads $\alpha - r_D(Z)$ monotonically increase in response to the increase in α in more competitive economies.[19]

While the sensitivity of spreads in response to contractionary policy contrasts with Dreschler et. al., the sensitivity of lending due to a drop in external funding D in response to contractionary policy when banks are near their leverage constraint is consistent with Kashyap and Stein. The failure to match the Dreschler et. al. spreads result depends on several factors. First, fed funds rates enter positively in the bank optimization problem in Dreschler, et. al. so that a rise in rates raises bank profitability ceteris paribus, while in our case rate rises enter negatively. This suggests that one should condition spread results on whether the bank is lending or borrowing in the fed funds market. Second, spreads depend on the elasticity of supply of deposits in the functional form of $r_D(N \cdot D)$. Specifically, the elasticity of supply of deposits depends on market structure as well as the parameters b and γ. [20] For our specific parameterization, the response of deposit rates to contractionary policy is not strong enough generate an increase in spreads in more concentrated markets. There is, however, a larger drop in deposits in the more concentrated $N = 2$ market than the $N = 3$ market which is consistent with Dreschler, et. al. The drop is just not enough to lead to a higher spread in the more concentrated market.

3.3 Other Policy and Technological Changes

3.3.1 Too-Big-To-Fail (TBTF)

In the previous sections, we assumed that in the event of bank failure, both the manager and the equity holders receive nothing. Here we generalize the environment to consider the implications of government commitment to a probability (denoted B) of a bailout to bank i. In the event of the bailout, a penalty as a fraction of bank value (denoted θ_M) is levied on the manager and equity holders retain some fraction (denoted θ_E) of the value of the bank.

[19] Under a symmetric equilibrium, the closed-form expression for the interest rate over deposits is given by:

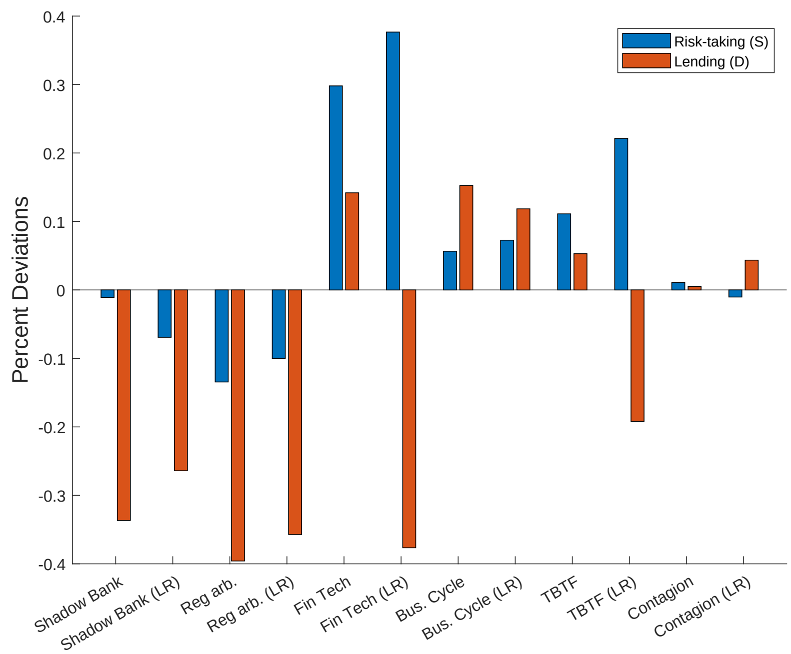
$$r_D = b + \frac{N}{N+1}\left(AS - b - \alpha\right),$$

which yields the following cross-partial with respect to α and N:

$$\frac{\partial^2 r_D}{\partial\alpha\partial N} = \frac{1}{(N+1)^2}\underbrace{\left(A\frac{\partial S}{\partial\alpha} - 1\right)}_{<0} + \frac{N}{N+1}A\underbrace{\frac{\partial^2 S}{\partial\alpha\partial N}}_{<0} < 0$$

[20] The elasticity of supply is given by $\epsilon = 1 + \frac{b}{\gamma \cdot N \cdot D}$.

Figure 7: Robustness



The problem of an incumbent manager is now to choose $S_i \in [0,1]$ and $D_i \leq \lambda E_i$ to solve[21]

$$V_i(N) = \max \pi_i(N) + \beta \left\{ p(S_i)V_i(N') + (1 - p(S_i)) \left[B \cdot \theta_M V(N') + (1 - B) \cdot 0 \right] \right\}. \quad (19)$$

Assuming a nonbinding leverage constraint, the first order condition of (19) with respect to D_i is unchanged while the first order condition with respect to S_i is now given by:

$$S_i : p(S_i) \cdot A \cdot D_i + p'(S_i) \cdot \{R_i \cdot D_i + \beta \cdot V_i(N') \cdot (1 - B \cdot \theta_M) = 0\} \quad (20)$$

which differs from (6) in the third "cost" term. In particular, now the cost of choosing more risk from lost future value is given by $-p'(S_i) \cdot \beta \cdot V_i(N') \cdot (1 - B \cdot \theta_M)$ which is lower than the benchmark case (identical when $B \cdot \theta_M = 0$). Thus, when the government commits to bailout banks with a positive probability, the moral hazard problem is exacerbated as expected.

The free entry condition now becomes

$$E_i(N) \equiv \frac{\pi_i(N)}{1 - \delta \left[p(S_i) + (1 - p(S_i)) \cdot B \cdot \theta_E \right]} \geq \kappa. \quad (21)$$

The free entry condition under TBTF differs from (8) in section 2.3.1 when $B \cdot \theta_E > 0$ and ceteris paribus can lead to more entry (i.e., greater competition in the long run). The agency wedge under TBTF now becomes

$$w(S_i) \equiv \frac{1 - \delta \left[p(S_i) + (1 - p(S_i)) \cdot B \cdot \theta_E \right]}{1 - \beta \left[p(S_i) + (1 - p(S_i)) \cdot B \cdot \theta_M \right]}. \quad (22)$$

When $\beta \leq \delta$, agency problems are exacerbated by bailouts in the short run when $\theta_E = \theta_M$.

This analysis introduces three new parameters: θ_E, θ_M, B. From Granja, Matvos, and Seru [43], bank failures impose substantial costs on the FDIC: the average cost of a failed bank sold at auction over the 2007 to 2013 period was approximately 28% of the failed bank's assets. Hence we take $\theta_E = \theta_M = 0.72$. Atkeson, et. al. [7] provide a decomposition of bank value into a component based on "franchise value" and a component based on government guarantees. They find that the value of government guarantees contributed 0.91 to the total gap between bank market and book values.[22] We choose $B = 0.8$ to match this value. We provide the results in the fifth set of bars of Figure 7 and columns 3 and 4 in Table A5.

In the short run, TBTF induces an increase in risk-taking as well as bank lending relative to the benchmark. The increase in risk-taking rises more than the increased cost of obtaining funding r_D so that interest margins and long-run profitability rise from the government

[21] Davila and Walther [28] examine a model in which big banks internalize their behavior on government bailout policies.

[22] That is, $\frac{(MVE-FVE)}{BVE} = 0.91$ where $\frac{MVE}{BVE} = 1 + \frac{FVE-BVE}{BVE} + \frac{MVE-FVE}{BVE}$ and MVE (FVE, BVE) is the market value (fair value, book value) of equity. For our calculations, we take FVE=BVE and take the model BVE to be the value of equity without the bailout to be calculated from the model when $B = 0$ and the model market value of equity to be calculated from the model with B set to the value consistent with the figure in Atkeson, et. al. [7].

subsidy. The large rise in government supported equity relative to the rise in deposit financing actually leads to a decrease in leverage.[23] The increase in lending offsets the lower probability of success to generate an expected increase in intermediated output as well as an increase in the expected cost of bailouts. Not surprisingly, the coefficient of variation in output and equity values rise.

In the long run, the increase in profitability induces entry chasing the government subsidy ultimately resulting in a more competitive banking sector (N rises by nearly 50%). This induces even more risk-taking and "over" lending. While interest margins rose in the short run, they fall in the long run with the increase in competition as does long-run profits. The impacts on output and expected bailout costs rise even more in the long run, as do the coefficients of variation.

3.3.2 Rise of Shadow Banks and Regulatory Arbitrage

As we have seen in Table A2, regulation in the form of tighter leverage constraints can lead to lower aggregate lending in the short and long run. This makes it likely that there will be increased competition from other financial institutions (i.e. shadow banks) to take up the slack in lending (i.e. regulatory arbitrage) which has been documented in an important paper by Buchak, et. al. [20].[24] That will affect the ability of incumbent banks to attract deposits. We model this as an exogenous increase in the slope (parameterized by γ) of the inverse deposit supply function $r_D(Z) = b+\gamma Z$. In particular, if γ rises, the cost of attracting deposits rises due to competition from un-modeled shadow banks (similar to rising costs from competition with other commercial banks that we have within the model).

We provide the results of increasing γ by 50% in the first set of bars in Figure 7 and columns 1 and 2 of Table A4. Increasing costs of external funding decreases individual and aggregate bank lending as well as risk-taking in the short run. Further, short run profits and equity values drop as well as intermediated output along with a drop in volatility of equity and output.

In the long run, however, decreased profitability of the banking sector leads to less entry (N drops by 16%) and a smaller banking industry. Less competition in the banking industry induces incumbent banks to take even less risk and lower leverage. This tends to amplify the short run changes.

Next we build on the above results and model the consequences of regulatory arbitrage by tightening leverage requirements (lowering λ such that the leverage constraint binds as in Section 3.2.1) coupled with the change in the elasticity of funding costs to the deposit rate implied by doubling γ Unsurprisingly, the combination of these two parametric changes tends to amplify the above changes.

[23]Increasing $B \cdot \theta$ for either the shareholder or manager will have monotonic and first-order increases in their valuation by the envelope theorem.

[24]Dempsey [29] studies how non-bank finance affects regulatory policy.

3.3.3 Fintech

Here we consider the impact of a better monitoring technology which raises the probability of success for any given level of chosen risk. In particular, we simply raise the parameter η in $p(S) = 1 - S^{\eta}$ from $\eta = 4$ in the benchmark to $\eta = 10$. We provide the results in Figure 7 and Table A4.

In the short run, despite the fact that risk-taking rises, the success probability rises substantially due to better screening.Lending increases resulting in higher intermediated output, as well as rising interest margins and equity values. Due to better screening, volatility of equity and output falls substantially. rise, while the volatility of equity falls. Given success probabilities rise, the cost of bailouts fall substantially. Intermediated output rises while its volatility drops.

The large rise in short-run equity values induces long-run entry. In particular, the number of banks more than doubles in the long run. This competition induces smaller banks (i.e. D drops in the long run) but aggregate lending is still higher than the benchmark due to entry. All other changes are dampened in the long run.

3.3.4 Business Cycle Boom

To understand how the banking industry responds to a boom (interpreted as an increase in productivity), we raise A by 25% (from 0.125 to 0.156). We provide the results in Figure 7 and Table A5.

In the short run, lending rises along with a rise in intermediated output. Thus, the model generates procyclical lending. Interest margins, short run profits, and equity values are all procyclical. Banks raise their risk taking scale S resulting in higher output and equity volatility (i.e. the variability of output and equity and failure rates are procyclical). Thus, under this parameterization, we get a counterfactual prediction about failure rates.

In the long run, entry rises in response to the increase in charter values so that we get procyclical entry. The increasing competition induces more risk taking in the long run.

3.3.5 Contagion and Runs

While the above framework focuses on how actions by one bank spills over to others due to strategic interaction in the external funding markets (as in Egan, Hortascu, and Matvos [35]), we now consider an alternative technology meant to capture, in a reduced form way, contagion and runs. In particular, we consider an identical environment except for the success probability function. In particular, we take $p(S_i, S_{-i}) = (1 - S_i^{\eta})(1 - S_{-i})^{\psi}$ with $S_{-i} = \overline{S}$. That is, bank i's choice of risk depends explicitly on what all other banks' choice of risk ($\overline{S}$) is under a symmetry assumption (i.e. the belief that all other banks will play $\overline{S}$). This specification nests our previous specification of success probability when $\psi = 0$. When $\psi > 0$, one may interpret this as a network externality in the spirit of Acemoglu, Ozdaglar, and Tahbaz-Salehi [3] or as collective moral hazard as in Farhi and Tirole [37]. We illustrate the effect by maintaining $\eta = 4$ at our benchmark value, but setting $\psi = 0.05$.

As in Bulow, Geanokoplos, and Klemperer [21], there are *strategic complementarities* if another player's strategy, say $\overline{S}$, increases the optimal strategy of bank i. In the left panel of figure 8, we plot the short run best response function S_i as a function of other banks' optimal choice of $\overline{S}$ for the calibration noted above for both our benchmark equilibrium where $\psi = 0$ and the contagion equilibrium where $\psi = 0.05$. [25] Clearly, as other banks choose more risky strategies, bank i chooses a riskier strategy consistent with strategic complementarity.

Another important feature of figure 8 is that if other banks are choosing the riskiest strategy (i.e. $\overline{S} = 1$), then since $p(S_i, S_{-i}) = 0$, bank i's profits are zero no matter what risky strategy it takes, so that $S_i = 1$ is one best response. This establishes that there can be multiple equilibria. The "run" equilibrium where $S_i = \overline{S} = 1$ implies a total loan market shutdown (i.e. a bad equilibrium as in Diamond and Dybvig [31]).

In the bottom panel of Figure 8 we plot the comparative statics of how risk taking and lending ($D = L$) change as we vary the degree of the externality ψ in a symmetric "no run" equilibrium associated with our benchmark calibration. Since $p(S, \overline{S})$ only affects the first order condition (6) for risk taking and not deposits in equation (7), a higher ψ only shifts FOC(S) in the graph. It is evident that as the externality gets stronger, banks take on more risk and lend more.

We provide the equilibrium results in Figure 8 and Table A5 for $\psi = 0.05$. In the short run, risk taking and lending rise due to the strategic complementarity. Equity values fall due to the decrease in success probability which also contributes to more variability in equity and output.

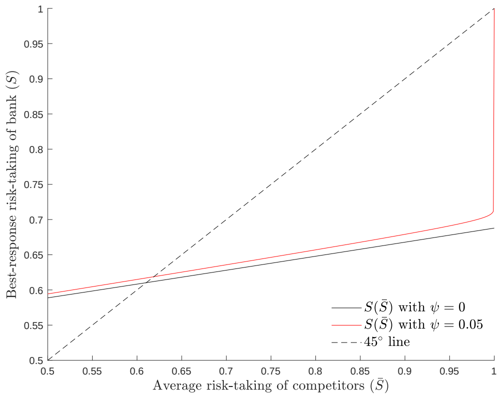
In the long run, entry falls in response to the decrease in charter values (N falls 6%). The decreasing competition induces less risk taking in the long run. Even though risk taking in the long run is lower than in the benchmark model, the probability of success still falls due to the externality. While individual lending rises even further, there is a fall in long run aggregate lending since there are fewer (albeit larger) banks.

4 Empirical Results and Model Validation

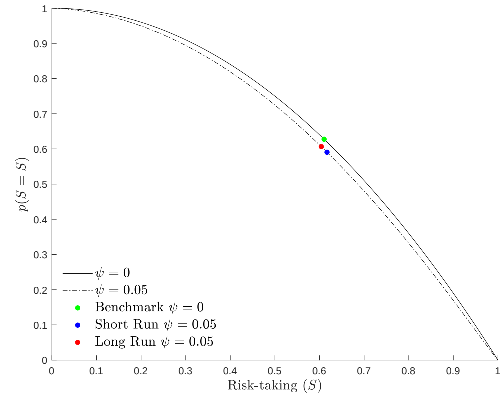
In this section, we evaluate empirically whether an intensification of the competitive environment facing a bank (1) reduces the bank's franchise (charter) value and (2) increases bank fragility. That is, we test a key set of predictions emerging from the model: By squeezing bank profit margins and depressing bank valuations, competition encourages bankers to make riskier investments.

[25] Specifically, we solve 3 equations (the first order conditions for risk taking and deposits for bank i and the first order condition for deposits for the other bank in 3 unknowns $(S_i, D_i, \overline{D})$ as a function of $\overline{S}$. We then perform checks that bank i has no incentive to deviate from the symmetric strategies.

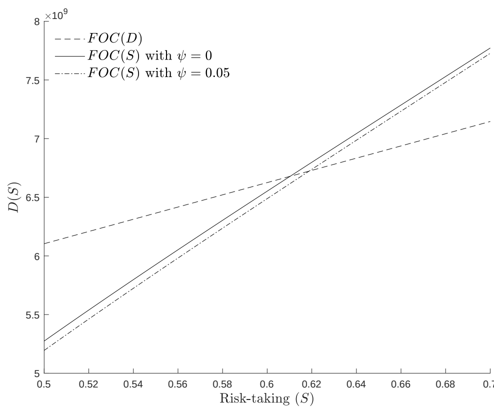
Figure 8: Contagion and Runs



(a) Best Response Function



(b) Comparative Statistics



(c) First Order Conditions

4.1 Empirical Challenges to Evaluating the Impact of Competition on Stability

An extensive academic literature examines the competition-stability nexus, offering conflicting results. Consistent with the competition-fragility view, for example, Keeley [52], Gan [39], Beck, Demirguc-Kunt, and Levine [11], Berger, Klapper, and Turk-Ariss [15], Beck, De Jonghe, and Schepens [15], and Buch, C., C. Koch, and M. Koetter [19] find that banks facing more competition are more fragile. In contrast, an influential line of research offers evidence that supports the competition-stability view, e.g., Barth, Caprio, and Levine [8], De Nicolo et. al. [30], Petersen and Rajan [58], Zarutskie [67], Schaeck, Cihak, and Wolfe [60], Boyd, De Nicolo, and Jalal [18], Houston et. al. [47], Fu, Lin, and Molyneux [38], Akins et. al. [5], and Carlson, Correia, and Luck [22].

Statistical and measurement challenges help account for these conflicting findings. The statistical challenges include endogeneity and, relatedly, omitted variable bias. For example, more stable banking markets might attract new banks to enter those markets. This could generate a positive correlation between stability and competition and lead observers to erroneously conclude that competition boosts stability. In terms of omitted variables, there might be factors that drive both competition and stability. For example, improvements in the regulatory environment might attract new banks and foster stability. Unless researchers account for those improved regulations in their analyses, the data will reveal a positive relationship between competition and stability and could lead observers to erroneously conclude that competition enhances stability.

Complexities with measuring competition also make it difficult to draw confident inferences about the relationship between bank competition and stability. Many use bank concentration, but concentration does not gauge the contestability of banking markets and therefore might ignore an important feature of the competitive pressures facing banks. As an example of the danger of using concentration as a proxy for competition, consider the U.S. banking system during the 1970s. There were over 30,000 banks. This large number of banks, however, reflected regulations that protected local monopolies; the low bank concentration metrics did not reflect intense competition. In this case, regulations produced low concentration and low competition.

Measuring bank risk is also not trivial. Many researchers use accounting-based measures, such as nonperforming loans, loan loss provision, loan charge-offs, profit volatility, risk-weighted assets, or a bank's the Z-score, but these accounting-based measures are subject to manipulation, as shown by JLL [49], and may vary across regulatory jurisdictions and over time as accounting rules change. An additional concern with using accounting-based risk measures relates to timing. A policy shock to the competitive environment that increases the riskiness of bank loans could take many years to affect nonperforming loans, loan losses, charge-offs, etc. The complex lag between changes in competition and accounting entries on bank balance sheets makes it difficult to match the timing of the shock to competition with accounting-based risk measures. Therefore, there are advantages to using market-based risk measures, since securities prices are (a) more likely to reflect immediately the expected present values of regulatory-induced changes in the competitive environments facing banks and (b) less subject to manipulation and regulatory changes that induce changes in accounting reports but that do not substantively affect the bank.

4.2 The JLL Empirical Methodology

JLL [50] address both the statistical and measurement challenges, thereby offering new evidence on the impact of bank competition on bank risk. In this subsection, we first describe their strategy for computing exogenous, regulatory-induced changes in the competitive environment facing individual banks and explain how we apply their identification strategy to our particular setting and questions. We then define the JLL market-based measures of risk that avoid the shortcomings associated with accounting-based risk metrics.

There are two key building blocks to constructing time-varying measures of the regulation-induced competitive pressures facing each bank holding company (BHC) in the United States over the 1982 to 1995. First, in a chaotic sequence of unilateral, bilateral, and multilateral reciprocal agreements over more than a decade, states lowered barriers to cross-state banking, increasing the contestability of banking markets. Specifically, for most of the 20th century, each state prohibited banks from other states from establishing affiliates within its borders. Starting in 1982, individual states began removing these restrictions. States started removing restrictions in different years and followed different dynamic paths in removing restrictions with different states over time. Some states unilaterally opened their borders. Most signed a series of bilateral and multilateral reciprocal agreements with other states, where the timing of these agreements differed by state-pairs and groups of states. This state-specific process of interstate bank deregulation continued until the Riegle-Neal Act effectively eliminated restrictions on well-managed, well-capitalized BHCs acquiring BHCs and bank subsidiaries in other states after September 1995. Earlier studies simply coded a state as "closed" or "open", and defined a state as open for all years after it first deregulated with any other state. JLL exploit the heterogeneity of each state's dynamic pattern of interstate bank deregulation. Thus, for each state and each year, they determine which other state's BHCs can establish subsidiaries in its borders.

The second key building block differentiates among BHCs within the same state and year. To do this, we apply the gravity model of investment to banks, as in Goetz, Laeven, and Levine ([40],[41]) and JLL ([49],[50]). For the case of banks, the gravity model assumes that the costs to a bank of establishing and effectively managing an affiliate increase with the geographic distance between the BHC's headquarters and the affiliate. Consistent with this gravity view of bank behavior, Goetz, Laeven, and Levine ([40],[41]) show that BHCs are more likely to expand into geographically close markets. The gravity model has important implications for the competitive pressures triggered by interstate bank deregulation.

The gravity model predicts that a BHC b headquartered in state k will experience a greater intensification of competition from BHCs in state j if BHC b is geographically closer to state j because it is less costly for state j's BHCs to establish subsidiaries closer to BHC b. That is, when Wyoming relaxes interstate banking restrictions with Montana, BHCs in northern Wyoming (e.g., banks in Sheridan) will experience a sharper increase in competition than BHCs in southern Wyoming (e.g., banks in Cheyenne).

JLL combine these building blocks to create time-varying measures of the competitive pressures facing each BHC. First, for each bank subsidiary in each year, identify those states banks that can enter the subsidiary's state and calculate the distance between the subsidiary and those states. Second, use the inverse of this distance as an indicator of the competitive pressures facing the subsidiary. Finally, calculate the competitive pressures facing each BHC by weighting these subsidiary-level competition measures by the percentage of each subsidiary's assets in the BHC. [26] By employing different methods for calculating the distance between each subsidiary and each of the other states, JLL construct several competition measures. For example, they use the distance between the subsidiary and the capitol of other states. They also construct synthetic measures of the geographic center of banking activity in each state and use this synthetic geographic location to compute the distance between the subsidiary and each other state. The results hold across the different distance measures. In our analyses, we use *Competition*, which is based on the distance

[26]For a more detailed explanation of the construction of competition measures, see JLL ([49],[50], [51]).

between the subsidiary and the capitols of the other states.

The time-varying, BHC-specific competition measure that we employ addresses several measurement and statistical concerns. First, it measures the contestability of markets, and therefore avoids the complications associated with inferring competition from market structure. Second, by combining the dynamic process of interstate bank deregulation with the geographic location of each bank, the competition measure differs by BHC and time. This addresses key endogeneity and omitted variable concerns as the statistical analyses can now control for time-varying state-year characteristics, such as changes in accounting rules, other regulatory reforms, changes in tax systems, economic conditions, etc. Thus, by employing this new competition measure, the analyses can now include state-year and BHC fixed effects that reduce the possibility that omitted variables that vary simultaneously with interstate bank deregulation drive the results.

JLL employ several market-based measures of bank risk that are based on stock return volatility, tail risk, and the residuals from asset pricing models. They find consistent results across the different risk measures. In our analyses, we focus on *Bank Risk*, which equals the natural logarithm of the standard deviation of daily stock returns.

Given these inputs, we assess the impact of competition on bank franchise (charter) value and bank risk using the following regression specification:

$$Y_{bst} = \gamma_C \cdot Competition_{bst} + \gamma_X' \cdot \mathbf{X}_{bst-1} + \theta_b + \theta_{st} \ + \varepsilon_{bst} \tag{23}$$

For BHC b, headquartered in state s, in year t, Y_{bst} is either *Franchise Value*, which equals the natural logarithm of the market value of the bank divided by the book value of assets or *Bank Risk*, which equals the natural logarithm of the standard deviation of daily stock returns. $Competition_{bst}$ is the measure of regulatory-induced competitive pressures facing BHC b in state s, in year t that is defined above. In addition, we include several time-varying BHC-level controls. Specifically, $\mathbf{X}_{bst-1}$ represents a vector of time-varying BHC traits, measured in period *t-1*, where *Leverage – Lagged* equals the BHC's debt to equity ratio one-year lagged, and *Ln(Total Assets)–Lagged* equals the natural logarithm of the BHC's total assets one-year lagged, and. Finally, the regressions control for bank (θ_b) and state-year (θ_{st}) fixed effects, and ε_{bst} is the error term. We report heteroskedasticity-consistent standard errors, clustered at the state level.

In evaluating the impact of competition on franchise value and risk, we focus on the estimate of γ_C. For example, consider the regression when the dependent variable is *Bank Risk*. If the estimated value of γ_C is greater than zero, this indicates that a regulatory-induced intensification of competition boosts bank risk. Although the model developed in Section 2 provides predictions about the impact of leverage requirements on bank risk taking, care must be taken in interpreting the coefficient estimate on *Leverage – Lagged* through the lens of the model. The model focuses on the maximum leverage ratio imposed by regulators, while the regression includes the actual debt-equity ratio of the BHC in year *t-1*. Thus, while the regression provides information on the relationship between leverage and risk, it does not quantify the impact of an exogenous change in the leverage requirement on risk.

4.3 The Impact of Competition

We find that an intensification of competition reduces charter value. As shown in column (1) of Table 3, *Competition* enters negatively and significantly in the *Charter Value* regression. Furthermore, the estimated economic impact of competition on BHC profits and franchise value is large. For example, consider a BHC that experiences a change in *Competition* from the 25^{th} percentile to the 75^{th} percentile of the sample distribution, which implies an increase in regulation-induced competition of 0.82. Then, the coefficient estimate from column (1) indicates that *Charter Value* would fall by about 50%. These results on charter value and profits are crucial because they validate the mechanisms underlying the competition-fragility view: competition reduces charter values, incentivizing bankers to take greater risks.

Table 3: Competition, Charter Value, and Risk

Competition, Charter Value, and Risk

	Charter Value			Bank Risk				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Bank Competition	-0.6146***	-0.6076**	-0.6296**	0.6618***	0.6572***	0.6704***	0.5994***	0.6265***
	(0.2242)	(0.2471)	(0.2468)	(0.1859)	(0.1992)	(0.1951)	(0.1778)	(0.1787)
Leverage-Lagged	-0.0320***	-0.0307***	-0.0322***	0.0243***	0.0234***	0.0244***	0.0119**	0.0142**
	(0.0077)	(0.0072)	(0.0075)	(0.0047)	(0.0048)	(0.0047)	(0.0048)	(0.0056)
Ln(Bank Assets)-Lagged	-0.3172***	-0.3235***	-0.3190***	-0.1978**	-0.1937**	-0.1968**	-0.1919**	-0.1968**
	(0.1117)	(0.1117)	(0.1125)	(0.0751)	(0.0776)	(0.0757)	(0.0748)	(0.0742)
% Institutional Ownership		0.6926***			-0.4530***		-1.1725***	
		(0.1895)			(0.0837)		(0.1968)	
Blockholders Top 10			0.4673**			-0.2711**		-1.1070***
			(0.2065)			(0.1150)		(0.2414)
Leverage*Institutional Ownership							0.0497***	
							(0.0129)	
Leverage*Blockholders-Top 10								0.0599***
								(0.0174)
Observations	1994	1994	1994	1994	1994	1994	1994	1994
R-squared	0.8496	0.8527	0.8507	0.7898	0.7925	0.7905	0.7945	0.7919

Notes: This table presents regression results of bank charter value and bank risk on bank competition and other bank traits. That sample consists of BHC-year observations from 1987 through 1995. In columns (1) (3), the dependent variable is Charter Value, which equals the natural logarithm of the market value of bank assets divided by the bank's book value of assets. In columns (4) to (8), the dependent variable is Bank Risk, which equals the natural logarithm of the standard deviation of daily stock returns. Bank Competition is the time-varying, BHC-specific measure of competition defined in the text. There are two proxies for the degree to which the bank has a large, institutional owner. % Institutional ownership equals the percentage of shares held by institutional investors and Blockholders Top 10 equals the percentage of shares held by the 10 largest institutional investors in this bank. The other BHC-level control variables include the size of the BHC, Ln(Bank Assets)-Lagged, which is the lagged value of the log of total bank assets, and Leverage-Lagged, which is the lagged value of the BHC's debt to equity ratio. The regressions also control for BHC and state-year fixed effects. Heteroskedasticity robust standard errors clustered at the state level are reported in parentheses. *, **, and *** indicate significant at 10%, 5%, and 1%, respectively.

Moreover, we find that an intensification of competition increases bank risk. Thus, we confirm the findings in JLL [50] using a regression specification derived from the model presented above. As shown in column (4) of Table 3, a regulatory-induced intensification of the competitive pressures facing a bank increases the riskiness of the bank (*Bank Risk*). The estimated impact is economically large. For example, again consider a BHC that experiences a change in *Competition* from the 25^{th} percentile to the 75^{th} percentile of the sample distribution, i.e., an increase of 0.82%. Column (4) estimates suggest that the *Bank Risk* would be 50% greater in the more highly competitive environment.

With respect to the other explanatory variables, the results confirm the predictions of our model. Consistent with the views that larger banks are better diversified (Goetz, Laeven, and Levine [41]) and perhaps also too-big-to-fail, we find that bank size, *Ln(Total Assets)–Lagged*, is inversely related to risk. Consistent with the view that more levered banks are more fragile, we find that *Leverage–Lagged* is positively associated with risk.

Banks can increase risk in several ways. They might increase lending to riskier clients, expand the maturity mismatch between assets and liabilities, become less diversified, or increase investments in non-loan activities and securities. JLL [50] show that a regulatory-induced intensification of competition boosts bank lending to riskier firms as measured by less profitable firms and firms closer to default. Although these results do not suggest that banks increase risk-taking only through this "lending to riskier firms" mechanism, these findings are consistent with our model, which predicts that competition induces banks to lend to riskier firms.

4.4 How Leverage and Governance Interact to Shape Bank Risk

As discussed above, the model offers insights into how leverage requirements and regulations on executive incentives interact to shape excessive risk taking by banks. In particular, the model explains how (under plausible parameterizations) a tightening of leverage requirements will have a bigger risk-reducing effect when bank executives are more concerned about the long-run profitability of the bank and hence less myopic. The intuition is as follows: forcing banks to be equity financed will reduce the excessive risk taking more if bank executives are more concerned about the equity value of the bank. The model also indicates that regulations that induce bank executives to focus less on short-run bonuses and more on the longer-run charter value of the bank will have a larger risk-reducing effect when the bank is less levered. The policy implication is potentially first-order: The result stresses that leverage requirements and regulations on executive incentives are reinforcing. It is not just that each independently reduces excessive risk taking; it is that each policy also magnifies the impact of the other policy. Put differently, tightening leverage requirements in the presence of myopic executives will have much weaker effects on bank stability than tightening leverage requirements when bank executives have less distorted incentives.

In this subsection, we turn to the data and assess whether empirical proxies for bank risk, leverage, and executive incentives co-move in ways consistent with these predictions from the model. Unlike the examination of competition, we do not evaluate the causal impact of leverage requirements, regulations on executive incentive, and the interactions of these policy levers on risk. Rather, we assess whether the patterns in U.S. data align with model simulations.

To conduct this assessment, we face a major challenge: constructing an empirical proxy for the degree to which bank executives maximize the long-run charter value of the bank. To construct this proxy, we would benefit from having data on executive "claw back" provisions, the degree to which each bank's board of directors reflects the interests of shareholders relative to those of executives, the details of executive compensation schemes, each executive's personal wealth exposure to the bank as a proportion of the executive's total wealth, etc. Such information, however, is not widely available for a large number of U.S. banks and their executives over a long time period.

We use a measure of the extent to which banks have large and informed owners, who can effectively compel bank executives to maximize the long-run value of the bank. We use (1) *% Institutional Ownership*, which equals the percentage of shares held by institutional investors and (2) *Blockholders Top 10*, which equals the percentage of shares held by the ten largest institutional investors in this bank. We assume (a) institutional investors are more informed than individual investors and (b) larger, more concentrated ownership teams can more effectively exert influence over bank executives. This suggests that banks with large *% Institutional Ownership* and *Blockholders Top 10* will effectively induce executives to maximize the long-run charter value of the bank. Consistent with this prediction, we find that *% Institutional Ownership* and *Blockholders Top 10* both enter positively and significantly in regressions in which Charter Value is the dependent variables, as shown in columns (2) and (3) of Table 3.

To examine empirically the relationship bank risk, leverage, and executive incentives, we modify regression (23) in Table 3 and include measures of executive incentives, either *% Institutional Ownership* or *Blockholders Top 10*, and the interaction between bank leverage (*Leverage-Lagged*) and these proxies for executive incentives. Our model predicts that

1. *% Institutional Ownership* and *Blockholders Top 10* will enter negatively: More concentrated, institutional ownership will incentivize executives to focus more on the long-run value of the bank, which will reduce risk-taking.

2. *Leverage-Lagged* will enter positively: More levered banks are riskier.

3. *% Institutional Ownership*Leverage-Lagged* (and *% Institutional Blockholders Top 10*Leverage-Lagged*) will enter positively: Fluctuations in leverage have a bigger impact on risk when executives have a longer-term focus than when executives are more focused on short-run performance metrics.

As shown in Table 3, the regression results are fully consistent with these predictions. Thus, the regression results help to validate the model, which makes the policy prediction that a tightening of leverage (or capital) requirements will have a bigger risk-reducing effect when other regulatory policies effective induce bank executives to focus more on the long-run value of the bank and less on short-run performance metrics.

4.5 How Monetary Policy Shapes Bank Risk

Next we examine empirically the effects of contractionary monetary policy on risk taking. In Section 3.2.2, we derived analytical predictions from the model that can be tested empirically by the signs of our regression coefficients in this section. The simulation results in Table A3 under our benchmark parameterization provide consistent testable predictions. Those predictions were: (i)$\frac{dS}{d\alpha} > 0$ so that in a regression of risk taking on the cost of monetary contraction (among other variables), we should predict the coefficient to be positive; (ii) $sgn(\frac{dS}{dN}) = sgn(\frac{dS}{d\alpha})$ so that in a regression of risk taking on a measure of competition, we should predict the coefficient to be positive; and (iii) $\frac{d^2S}{d\alpha dN} < 0$ so that in a regression of risk taking on the interaction between monetary contractions and competition, we should predict a negative coefficient.

In the remainder of this subsection, we test the prediction that tightening monetary policy will increase bank risk but it will increase bank risk by less among banks in more competitive environments. We use the same core regression specification and measures of bank risk and competition employed in Table 3.

A key challenge is finding an empirical proxy for monetary policy in the model, i.e., the model's α. The primary monetary target during our sample period is the Federal Funds Rate (FFR), which varies over time but not across states or banks. The focus of our analyses, however, is on how the impact of monetary policy differs by the competitive environment and we measure competition at the BHC-time level.

To address this challenge, we create four time-varying, BHC-specific measures of monetary policy. These measures are based on the assumption that banks that rely more on deposits (i.e. those with less access to non-deposit finance) are more sensitive to changes in the FFR, because they have less access to elastic financing sources if, for example, the FFR increases. FFR_1 is the FFR averaged over the year interacted with the degree to which the BHC relies on non-wholesale deposits, lagged one year: FFR_t*[(total deposits – wholesale deposits)/bank liabilities$]_{t-1}$. FFR_2 is defined similarly, except rather than measuring the FFR over the year, it is measured during the first quarter of the year. FFR_3 is the FFR averaged over the year interacted with the degree to which the BHC funds itself with deposits, lagged one year: FFR_t*[(bank liabilities – non-deposit liabilities)/bank liabilities$]_{t-1}$. FFR_4 is defined similarly to FFR_3, except that rather than measuring the FFR over the year, it is measured during the first quarter of the year.

We next test the model's predictions. To do this, we examine both the linear monetary policy proxy, for example FFR_1, and the interaction between monetary policy and competition, for example FFR_1**Bank Competition.* The model predicts that the linear monetary policy terms will enter positively (tighter monetary increases bank risk) and the interaction term enters negatively (the increase in bank risk associated with tighter monetary policy is less among banks in more competitive environments).

As shown in Table 4, the regression analyses confirm the model's predictions. For each of the four monetary policy proxies we find that tighter monetary policy is associated with (1) an increase in bank risk and (2) a smaller increase in bank risk among banks in more competitive environments. That is, the linear monetary policy variable enters with a positive and significant coefficient and the interaction term enters with a negative and significant coefficient. It is valuable to note that in no case do the estimates suggest that a tightening of monetary policy reduces bank risk. That is, even when the interaction term is evaluated at the maximum value of *Bank Competition* (2.166), the absolute value of the interaction term is smaller than the coefficient on the linear monetary policy variable. Furthermore, and also consistent with the model, *Bank Competition* continues to enter with a positive and significant coefficient.

Table 4: Monetary Contractions and Risk

Competition, Monetary Policy, and Bank Risk

	Bank Risk			
	(1)	(2)	(3)	(4)
Bank Competition	0.6221**	0.6988**	0.5963**	0.7011**
	(0.2623)	(0.2934)	(0.2716)	(0.2847)
Leverage-Lagged	0.0300***	0.0307***	0.0297***	0.0308***
	(0.0051)	(0.0050)	(0.0049)	(0.0049)
Ln(Bank Assets)-Lagged	-0.1645*	-0.1615*	-0.1580*	-0.1619*
	(0.0900)	(0.0889)	(0.0897)	(0.0867)
FFR_1	1.0835**			
	(0.4301)			
*FFR_1*Bank Competition*	-0.4177*			
	(0.2136)			
FFR_2		2.2895***		
		(0.5305)		
*FFR_2*Bank Competition*		-0.9277***		
		(0.3384)		
FFR_3			1.3956***	
			(0.4059)	
*FFR_3*Bank Competition*			-0.4701***	
			(0.1614)	
FFR_4				2.0084***
				(0.7139)
*FFR_4*Bank Competition*				-0.6102**
				(0.2777)
Observations	1518	1518	1518	1518
R-squared	0.8183	0.8182	0.8188	0.8175

Notes: This table presents regression results of bank risk on bank competition, monetary policy, the interaction between monetary policy and competition and other bank traits. That sample consists of BHC-year observations from 1987 through 1995. The dependent variable, Bank Risk, equals the natural logarithm of the standard deviation of daily stock returns. Bank Competition is the time-varying, BHC-specific measure of competition defined in the text. As also defined in the text, the regressions include four time-varying, BHC-specific proxies of the Federal Funds Rate (FFR_1, FFR_2, FFR_3, and FFR_4), which is the monetary policy component of each BHC's cost of funds, i.e., α in the model. The other BHC-level control variables include the size of the BHC, Ln(Bank Assets)-Lagged, which is the lagged value of the log of total bank assets, and Leverage-Lagged, which is the lagged value of the BHC's debt to equity ratio. The regressions also control for BHC and state-year fixed effects. Heteroskedasticity robust standard errors clustered at the state level are reported in parentheses. *, **, and *** indicate significant at 10%, 5%, and 1%, respectively.

4.6 Summary

There are two big messages emerging from the regression analyses. First, an intensification of the competitive environment facing a bank lowers it franchise value and increases risk taking. There is a material tradeoff between competition and stability. The second message is that key predictions of the model developed in Section 2 hold in the data. Not only do the data confirm the model's predictions that intensifying competition lowers franchise value and increases risk, the empirical results are also consistent with the model's predictions about how leverage and executive incentives shape bank risk as well as how monetary policy affects bank risk taking. The consistency between the model's predictions and the economic results is valuable because it increases confidence in the findings that emerge from calibrating the model and running policy simulations.

5 Conclusion

In this paper, we addressed three questions: Does bank competition reduce bank stability? How can policymakers use available regulatory tools to maximize the efficiency benefits while minimizing any adverse risk effects of competition? How does the effectiveness of monetary policy depend on bank competitiveness?

Based on an analytical model that is calibrated to reflect the U.S. banking industry and econometric evidence, we discover the following:

1. An intensification of bank competition tends to (a) squeeze bank profit margins, reduce bank charter values, and spur lending and (b) increase the fragility of banks. There is a competition-stability tradeoff.

2. Policymakers can get the efficiency benefits of competition without the fragility costs by enhancing bank governance and tightening leverage requirements. In particular, we find that (a) legal and regulatory reforms that induce a bank's decision makers (executives and influential shareholders) to focus more on the long-run value of the bank and less on shorter-run objectives tend to increase both efficiency and stability; (b) tightening leverage requirements also increases bank stability; and (c) combining policies that enhance the governance of banks with those that tighten leverage has a positive, multiplicative effect that materially boosts bank efficiency and stability.

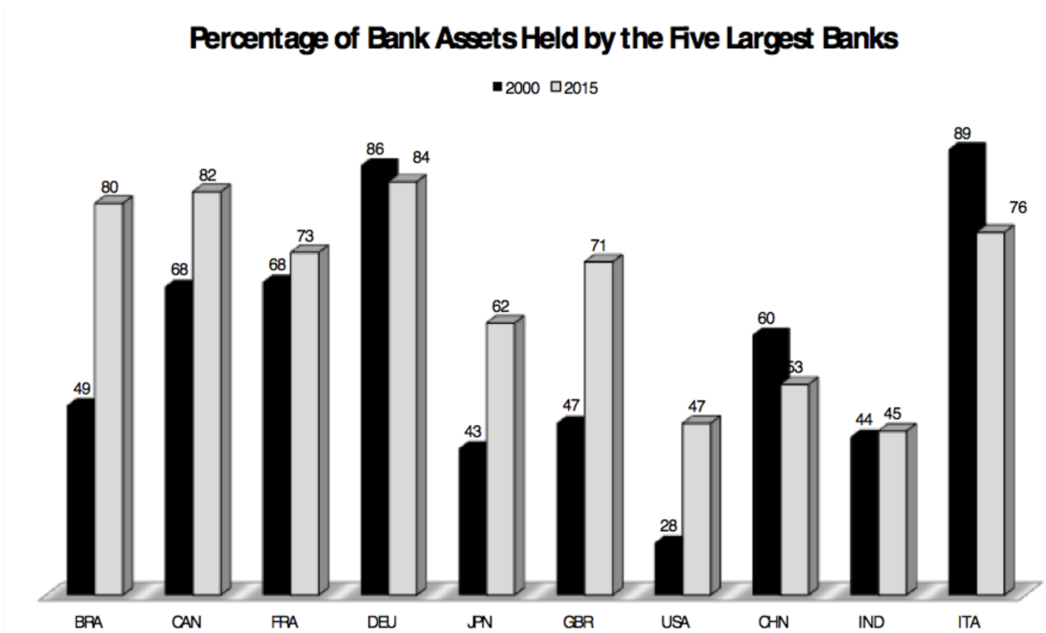
   These findings highlight the enormous welfare benefits of legal and regulatory reforms that improve the incentives of bank decision makers, i.e., that improve bank governance. Such reforms improve bank efficiency, reduce bank fragility, allow for a more competitive banking system without increasing bank fragility; and bolster the effectiveness of capital requirements.

3. Competition intensifies the impact monetary policy on bank lending. In uncompetitive banking environments where banks enjoy large interest rate spreads and profit margins, banks can cushion the effects of monetary policy on bank lending. However, in more competitive banking markets, small interest spreads and profit margins forces banks to

respond more aggressively to monetary policy changes. The structure of the banking system is an important consideration in assessing the likely effects of monetary policy on the economy. This is important since many models that central banks use to assess the impact of monetary policy assume competitive banking markets, while most banking markets are highly concentrated.

Besides these policy messages, this paper offers a tool to central banks and other analysts. Despite the richness of predictions from our model, it amounts to solving three equations (optimality conditions for risk taking, lending, and entry) in three unknowns. The model allows for regulations that influence (a) the regulatory costs of entering the banking industry, (b) leverage requirements, and (c) bank governance. While other models include subsets of these features, our model combines them all, so that we can quantify the likely effects of bank regulatory and monetary policies on the economy.

Figure 9: International Bank Concentration Across Time



Source: World Bank Global Financial Development Database.

While we have calibrated our model to the U.S. banking industry, our calibration can be modified to fit other economies and thereby provide a tool for quantifying the impact of bank regulatory and monetary policies on those economies. Figure 9 graphs the percentage of banking system assets controlled by the five largest banks in 2000 and 2015 (*5 Bank Concentration*) in the ten largest economies. It is clear there is considerable variation in concentration across countries and time. The figure highlights two important features. First, six out of the ten countries had *5 Bank Concentration* greater than 70% in 2015. This motivated us to build a model that allows for highly concentrated, potentially noncompetitive banking industries. Second, *5 Bank Concentration* grew by over 60% in Brazil and the United States and shrunk by over 10% in China and Italy from 2000 to 2015. Thus, we build a dynamic model of the banking system in which a variety of policies can trigger endogenous changes in the competitiveness of the banking industry.[27]

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Appendix

A Supplementary Model Tables

Table A1: Variation in Market Structure

	Planner	Less competitive	Benchmark (levels)	More competitive **	Optimal entry barriers
N	NA	1	3	5	2
S	-5.4%	-35.8%	0.61	3.5%	-15.2%
D	NA	65.9%	6678.48	-37.7%	23.7%
Z	-22.6%	-44.7%	20035	3.9%	-17.5%
D/E	NA	-79.6%	15.56	17.0%	-48.7%
p	6.2%	34.0%	0.63	-4.2%	16.7%
R	NA	2.6 bp	0.04	-0.2 bp	1.0 bp
r_D	NA	-5.3 bp	0.006	0.5 bp	-2.1 bp
π^*	NA	271%	167.95	-43.3%	78.5%
E^*	NA	713%	429.25	-46.7%	141%
V	NA	370%	269.38	-44.7%	98.5%
F/Y	NA	-657%	0.035	123%	-383%
Y^*	-22.1%	-52.1%	959.17	3.0%	-18.4%
cv(Y)	-34.4%	-85.4%	569.21	15.0%	-49.7%
cv(E)	NA	-44.8%	0.77	5.7%	-21.5%

Except for benchmark, all columns are percent deviations from benchmark. * denotes a row is in millions. ** denotes that the debt to equity ratio binds in that column. $Y = p(S) \cdot A \cdot S \cdot Z$

Table A2: Regulatory Policy Counterfactuals: Short-Run versus Long-Run

	Mitigating agency SR	Mitigating agency LR	Tightening leverage SR **	Tightening leverage LR **	Agency and leverage SR **	Agency and Leverage LR **
N	3	3.08	3	6.56	3	7.01
S	-2.7%	-1.8%	-29.7%	-28.2%	-29.8%	-28.8%
D	-1.3%	-2.7%	-39.8%	-69.8%	-37.5%	-70.3%
Z	-1.3%	-0%	-39.8%	-34.0%	-37.5%	-32.3%
D/E	-6.7%	-2.7%	-71.1%	-71.1%	-69.0%	-70.3%
p	3.2%	2.1%	30.0%	28.8%	27.6%	27.6%
R	-0.05 bp	-0.1 bp	2.5 bp	1.9 bp	2.2 bp	1.7 bp
r_D	-0.2 bp	-0.02 bp	-4.8 bp	-4.1 bp	-4.4 bp	-3.9 bp
π^*	0.5%	-3.3%	27.4%	-42.4%	24.8%	-45.4%
E^*	5.8%	0%	108.2%	0%	101.6%	0%
V	8.1%	3.3%	56.2%	-30.3%	56.0%	-31.2%
F/Y	-29.5%	-8.4%	-462%	-411%	-571%	-409%
Y^*	-0.9%	0%	-45.0%	-39.0%	-44.0%	-38.5%
cv(Y)	-9.2%	-5.5%	-79.1%	-75.6%	-78.4%	-75.6%
cv(E)	-4.3%	-2.8%	-38.4%	-36.8%	-37.9%	-37.0%

Column 1-4: Percent deviations from the benchmark. Columns 5-6: Percent deviations from mitigating agency. $Y = p(S) \cdot A \cdot S \cdot Z$. Note here that the entry cost *kappa* is held fixed and so in the short-run equity $E^* \neq \kappa$. * denotes a row is in millions. ** denotes that the debt to equity ratio binds in that column. Columns 1-2 increase β from 0.60 to 0.65. Columns 3-4 impose the leverage constraint of $\lambda = 4.5$.

Table A3: Monetary Transmission Mechanism Across Market Structures

	Benchmark less competitive (levels, N=2)	Contractionary Monetary Policy SR (N=2)	Contractionary Monetary Policy LR (N=2)	Benchmark (levels)	Contractionary Monetary Policy SR (N=3)	Contractionary Monetary Policy LR (N=3)	Benchmark more competitive (levels, N=4) **	Contractionary Monetary Policy SR (N=4) **	Contractionary Monetary Policy LR (N=4) **
N	2	2	1.9	3	3	2.88	4	4	3.84
S	0.52	2.0%	0%	0.61	1.5%	0%	0.63	0%	0%
D	8261.2	-2.5%	0%	6678.5	-2.4%	0%	5202.3	-4.7%	0%
Z	16522	-2.5%	-5.0%	20035	-2.4%	-4.2%	20809	-4.7%	-4.0%
D/E	7.99	7.7%	0%	15.56	7.2%	0%	18.2	0%	0%
p	0.732	-1.4%	0%	0.628	-1.8%	0%	0.60	0%	0%
R	0.050	-0.12 bp	0 bp	0.04	-0.10 bp	0 bp	0.038	0.9 bp	0 bp
r_D	-0.015	-0.25 bp	-0.5 bp	0.006	-0.3 bp	-0.5 bp	0.011	-0.6 bp	-0.5 bp
Sp	0.045	0.75 bp	1.0 bp	0.024	0.8 bp	1.0 bp	0.019	1.1 bp	1.0 bp
π^*	299.77	-6.3%	0%	167.95	-6.5%	0%	119.08	-2.5%	0%
E^*	1034.1	-9.5%	0%	429.25	-9.0%	0%	285.84	-4.7%	0%
V	534.59	-7.1%	0%	269.38	-7.2%	0%	186.31	-1.0%	0
F/Y	-0.084	-20.8%	-33.6%	0.048	-44.8%	-80.5%	0.091	-53.9%	-46.1%
Y^*	782.62	-2.1%	-5%	959.17	-2.7%	-4.2%	987.67	-4.7%	-4%
cv(Y)	286.43	3.3%	-5.0%	569.21	2.0%	-4.2%	654.46	-4.6%	-4.0%
cv(E)	0.61	2.7%	0%	0.77	2.4%	0%	0.81	0%	0%

Column 2-3, 5-6, and 8-9 illustrate percent deviations from the benchmark ($N = 2, N = 3$, and $N = 4$ respectively) for a monetary policy contraction that increases α from 0.03 to 0.035. * denotes a row is in millions. ** denotes that the debt to equity ratio binds in that column.

Table A4: Robustness Part I

	Shadow Banking SR (γ)	Shadow Banking LR (γ)	Regulatory Arbitrage SR ($\gamma + \lambda$) **	Regulatory Arbitrage LR ($\gamma + \lambda$) **	Fintech SR (η)	Fintech LR (η)
N	3	2.5	3	2.76	3	6.57
S	-1.1%	-6.9%	-13.4%	-10%	29.8%	37.6%
D	-33.7%	-26.4%	-39.6%	-35.7%	14.2%	-37.6%
Z	-33.7%	-38.6%	-39.6%	-40.9%	14.2%	36.5%
D/E	-2.7%	-26.4%	-35.7%	-35.7%	-80.7%	-37.7%
p	1.3%	7.9%	14.9%	11.3%	43.8%	31.4%
R	-0.02 bp	0.4 bp	0.1 bp	0.6 bp	0.6 bp	-1.5 bp
r_D	-0.06 bp	-0.9 bp	-1.1 bp	-1.4 bp	1.7 bp	4.4 bp
π^*	-33.2%	-12.3%	-28.8%	-17.6%	87.5%	-48.9%
E^*	-31.8%	0%	-6%	0%	490%	0%
V	-31.2%	-7.9%	-21.1%	-11.5%	135%	-36.9%
F/Y	-17%	-201%	-227%	-276%	-56.8%	160%
Y^*	-33.6%	-38.3%	-39.9%	-40.9%	113%	147%
cv(Y)	-35.8%	-50.5%	-60.8%	-56.9%	-61.3%	-11.7%
cv(E)	-1.7%	-10.3%	-19.2%	-14.7%	-57.4%	-40.2%

In the first two experiments γ is increased by 50%. The regulator experiment also decreases λ to 10. The Fintech experiment corresponds to η being increased from 2 to 10. The non-interest income experiment corresponds to setting $\epsilon = 5e^6$. * denotes a row is in millions. ** denotes that the debt to equity ratio binds in that column.

Table A5: Robustness Part II

	Business Cycle SR (A)	Business Cycle LR (A)	Too Big To Fail SR ($B = 0.8$)	Too Big To Fail LR ($B = 0.8$)	Contagion SR ($\psi = 0.05$)	Contagion LR ($\psi = 0.05$)
N	3	3.16	3	4.47	3	2.81
S	5.7%	7.3%	11.1%	22.1%	1.1%	-1.0%
D	15.3%	11.8%	5.3%	-19.2%	0.5%	4.3%
Z	15.3%	17.7%	5.3%	20.5%	0.5%	-2.1%
D/E	3.2%	11.8%	-56%	-19%	15.4%	4.4%
p	-6.9%	-8.9%	-13.9%	-29%	-5.9%	-3.4%
R	0.6 bp	0.5 bp	0.2 bp	-0.8 bp	0 bp	0.1 bp
r_D	1.8 bp	2.1 bp	0.6 bp	2.4 bp	0 bp	-0.3 bp
π^*	23.7%	13.9%	-4.6%	-53.7%	-4.9%	5.2%
E^*	11.7%	0%	141%	0%	-12.9%	0%
V	18.2%	8.1%	18%	-41.6%	-7.6%	3%
F/Y	364%	444%	225%	1042%	23%	-56%
Y^*	41.7%	81.6%	0.7%	4.2%	-4.4%	-6.4%
cv(Y)	69.9%	81.6%	44%	119%	11.7%	2.3%
cv(E)	9.5%	12.4%	19.7%	45.1%	8.1%	4.5%

In the first two experiments A is increased by 25%. The TBTF experiment moves bailout probability from 0 to $B = 0.8$ with $\theta = 0.72$. The contagion experiment moves the externality of other banks risk-taking on a given banks success probability from $\psi = 0$ to $\psi = 0.05$. * denotes a row is in millions. ** denotes that the debt to equity ratio binds in that column.

B Summary of Solution Methods

This section will describe in high-level the solution method for the various models. The code, which can be found here:

$$https://sites.google.com/a/wisc.edu/deancorbae/research/CorbaeLevineCode\_191212.zip$$

provides documented code to replicate the results and can be used to calibrate to different economies.

There are broadly 4 versions of the model that require different solution procedures.

1. Solving model without leverage constraint binding
2. Solving model with leverage constraint binding
3. Computing long run equilibrium
4. Computing short run transition equilibrium

B.1 Model without leverage constraint binding

The following procedure is used to generate appendix Table A1. Furthermore, it is used for all long run and short run transitions as well.

To solve the unconstrained model, we find optimal choices S and D by solving the FOC of S and D (equations 6 and 7, respectively). The optimal choice in D is a direct function of S by the FOC of D. Therefore, by plugging this into the FOC of S, we only need to solve for one non-linear equation in S.

1. Set desired parameterization
2. Create a grid of risk choice $S_0 \in [0, 1]$ that will serve as initial seeds
3. For each initial seed S_0, minimize FOC to zero as close as possible
4. Check if the S^* found above is indeed a best response (assuming everyone else plays S^*, see if there is a profitable deviation)
5. If not best response, discard. If it is also a best response, keep.
6. After trying all the S_0 seeds, from the candidate S^*, pick the one that gives the highest bank value (this is the global maximum)
7. Evaluate all other equilibrium variables from S^* and D^*

B.2 Model with leverage constraint binding

The following procedure is used to generate columns 3 and 4 in appendix Table A2 and the regulatory arbitrage experiments.

The procedure here equivalent to above. However, the FOC conditions we use are different. We find optimal choices S and D by solving the FOC of S and D (equations 6 and 13, respectively). The optimal choice in D is pinned down directly by the binding leverage constraint now. This is in turn a direct function of E^*. Equation 28 shows E^* as a direct function of S. Therefore, by plugging this into the FOC of S, we again only need to solve for one non-linear equation in S.

B.3 Computing long run equilibrium

The following procedure is used to generate all long run equilibria.

1. Given a market size N, solve the model (according to whether it is constrained or unconstrained) and find the implied entry cost
2. Check if this implied entry cost is equal to the original benchmark entry cost κ
3. If yes, stop you've found the long run equilibria market size N. If not, search over a different N until the implied entry cost is the original κ

B.4 Computing short run transition equilibrium

The following procedure is used to generate all short run transition equilibria.

Solution procedure here is equivalent to solving the constrained and unconstrained models except the the value function changes from equation 4 to equation 17. Therefore, the FOC for D does not change, but the FOC for S changes from equation 6 to equation 18.

Take the long run value from the long run equilibrium solution as $V_{\Theta'}(N')$ and plug into the new FOC. The rest of the algorithm is the same.

C Planner's Solution

C.1 First Order Conditions

An interior solution to (1) is given by the first order conditions:

$$\begin{aligned}\frac{\partial \mathcal{O}}{\partial S} &= 0 : p'(S) \cdot A \cdot S \cdot Z + p(S) \cdot A \cdot Z = 0, \\ \frac{\partial \mathcal{O}}{\partial Z} &= 0 : p(S) \cdot A \cdot S - 2\widetilde{\gamma} Z = 0.\end{aligned}$$

Solving these two equations in two unknowns yields (S^*, Z^*) in (2) of Section 2.2.

C.2 Second Order Conditions

Necessary and sufficient conditions for a local interior maximum in the Planner's problem are: (I) $O_{ZZ} < 0$, and (II) $det = O_{ZZ}O_{SS} - O_{ZS}^2 > 0$.

First $O_{ZZ} = -2\gamma < 0$ for any $\gamma > 0$ so (I) is always satisfied. Second, using the solution for S^*, at the optimum $O_{ZS}^* = A[-\eta S^\eta + (1 - S^\eta)] = 0$ and hence $det > 0 \iff O_{SS} < 0$. Since $O_{SS} = -2\eta^2 A S^{\eta-1} Z$ it follows that for any interior solution we have an interior maximum.

D Decentralized Solution

D.1 Second Order Conditions

We begin with the case where the leverage constraint is non-binding. Let $F(S, Z) = \pi(S, Z) + \beta p(S)V$. Then, the second derivatives are:

$$\begin{aligned}
F_{SS} &= p''(S) \cdot R(S, Z) \cdot D + p'(S) \cdot A \cdot D + p'(S) \cdot A \cdot D + \beta \cdot p''(S) \cdot V \\
F_{DD} &= -p(S) \cdot \gamma - p(S) \cdot \gamma = -2\gamma p(S) < 0 \\
F_{SD} &= p'(S) \cdot R(S, Z) - p'(S) \cdot \gamma \cdot D + p(S) \cdot A = p(S) \cdot A
\end{aligned}$$

where we used $p'(S) = -2S$ and $p''(S) = -2$ for the first inequality, and the last equality above follows from Eq. (7). The necessary condition for a local optimum is then

$$F_{SS} \cdot F_{DD} - F_{DS}^2 > 0 \tag{24}$$

Inequality (24) places restrictions on the set of parameters we need to ensure a local maximum. Numerical checks of all local maxima (and boundaries) ensures global optimality.

When the leverage constraint is binding, notice here that the constraint is linear in D alone, so the determinant bordered hessian condition (see Theorem 5.5 in Sundaram [62]) for a constrained local max reduces to requiring $F_{SS} < 0$.

D.2 Non-Linear Interaction of Binding Leverage Constraints and Manager Myopia

In Section 3.2, we found numerically that the differential impact of tightening leverage constraints with different levels of manager myopia $\Delta(S; \beta_L = 0.90) < \Delta(S; \beta_H = .99)$. However, there can be cases where the sign is reversed. Here we provide a discussion of those countervailing forces.

Totally differentiating the first order condition for S in the leverage constrained region given by (14) with respect to λ and β yields:

$$\frac{dS}{d\lambda} = -\frac{Ap(S)^2}{den} > 0$$

$$\frac{dS}{d\beta} = \frac{-p'(S)p(S)w(S)}{den \times (1 - \beta p(S))} < 0$$

where

$$den = [2A\lambda p'(S)p(S) + p'''(S)p'(S)] < 0 \tag{25}$$

with

$$w'(S) = \frac{-p'(S)}{[1-\beta p(S)]^2}(\delta - \beta) > 0. \tag{26}$$

Then the local interaction effect is given by

$$\frac{\partial^2 S}{\partial\lambda\partial\beta} = \frac{A[p'(S)p(S)]^2 w(S)}{(1-\beta p(S)) \times den^2} > 0.$$

This expression implies a complementarity in tightening leverage constraints and reducing agency costs, when it occurs. The non-monotonic relation arises when switching from an unconstrained equilibrium to a leverage constrained equilibrium.

D.3 Invariance of Rise in Shadow Banking in the model

Although from (12) holding Z fixed the interest margin explicitly depends on γ, in equilibrium we have $Z = \frac{N(AS-\alpha)}{\gamma(N+1)}$ so that $R = \frac{\gamma}{N}\frac{N(AS-\alpha)}{\gamma(N+1)} = \frac{AS-\alpha}{N+1}$ in equilibrium. Thus, interest margins are invariant to γ outside of potentially a second order effect of γ changing S. As it turns out, plugging this solution of R into (11) and using the equilibrium level of $E[N^C] = \frac{p(S^C)R^C D^C}{1-p(S^C)\delta}$ we see that $\frac{1}{D}E[N^C]$ cancels out the only other potential dependence on γ. Thus, risk-taking S is also invariant to γ.

E Analytical comparative statics

Obtaining optimal policies

Define $R^i = AS - \gamma(Z_- + D) - \alpha$.
The problem for a bank is:

$$\max_{S,D} p(s) \cdot R^i \cdot D + \beta \cdot p(S) \cdot V(N')$$

FOC wrt D implies

$$R^i = \gamma D$$

Imposing symmetry and solving we get

$$D = \frac{(AS-\alpha)}{\gamma(N+1)}.$$

FOC wrt S

$$p'(S)[R^i D + \beta V] + p(S)AD = 0$$

Imposing symmetry, using $V = \frac{p(S)R^i D}{1-\beta p(S)} = \frac{\gamma D^2}{1-\beta p(S)}$ and the solution of D we have

$$p'(S)[\gamma D^2 + \gamma\beta p(s)\frac{1}{1-\beta p(S)}D^2] + p(S)AD = 0$$

Simplifying

$$Rp'(S) + p(S)(1 - \beta p(S))A = 0 \qquad (27)$$

where the final solution is obtained by substituting the solution for $R = \frac{(AS-\alpha)}{N+1}$ into above and where $p(S) = 1 - S^\eta$, $p'(S) = -\eta S^{\eta-1}$, $p''(S) = -\eta(\eta-1)S^{\eta-2}$.

First-order effect of monetary policy

Risk-taking:
Total differentiating the implicit solution for S (27) we have

$$\left[p''(S)R + p'(s)\frac{A}{N+1} + p'(S)A(1-\beta p(S)) - p(S)\beta p'(S)A\right]dS - p'(S)\frac{1}{N+1}d\alpha = 0$$

Define $[] = den$ then re-arranging

$$\frac{dS}{d\alpha} = \frac{p'(S)}{(N+1)den}$$

Using the definition of $p(S)$,

$$den = -\eta S^{\eta-2}\left((\eta-1)\frac{(AS-\alpha)}{N+1} + \frac{AS}{N+1} - AS(2\beta p(S)-1)\right)$$

Thus, defining $\widetilde{den} = (...)$ we have that

$$\begin{aligned}\frac{dS}{d\alpha} &= \frac{p'(S)}{(N+1)(-\eta S^{\eta-2})\widetilde{den}}\\ &= \frac{S}{(N+1)\widetilde{den}}.\end{aligned}$$

So that the sign of the first derivative depends on the sign of $\widetilde{den}$.

Now by definition of $\widetilde{den}$ we have

$$\widetilde{den} = (\eta-1)R + \frac{AS}{N+1} - AS(2\beta p(S)-1)$$

$$\widetilde{den} = \widetilde{den} \pm \frac{\alpha}{N+1} \pm \alpha(2\beta p(S)-1)$$

letting $x = (2\beta p(S)-1)(N+1)$ we have

$$\widetilde{den} = R(\eta-1) + (1-x)[R + \frac{\alpha}{N+1}].$$

As is shown in the appendix a sufficient condition for $\widetilde{den} > 0$ is given below:

$$\eta \geq (2\beta p(S)-1)(N+2) \Rightarrow \widetilde{den} > 0. \tag{28}$$

Clearly for η sufficiently large this condition will always be satisfied. Furthermore, evaluating at the baseline parameters this condition is satisfied.

$$\frac{dS}{d\alpha} = \frac{S}{(N+1)\widetilde{den}} = \begin{cases} > 0 & \eta \text{ large ie satisfying (28)} \\ < 0 & \eta \text{ small ie satisfying (34)} \\ \text{ambig} & \text{else} \end{cases} \tag{29}$$

Lending:
Now using the solution for $D = \frac{AS-\alpha}{\gamma(N+1)}$,

$$\frac{dD}{d\alpha} = \frac{A\frac{dS}{d\alpha} - 1}{\gamma(N+1)}$$

Let's suppose that $\widetilde{den} > 0$ so that $\frac{dS}{d\alpha} > 0$. (If this is not the case, then we have immediately that $\frac{dD}{d\alpha} < 0$.) then defining $y = (N+1)\widetilde{den}$

$$\frac{dD}{d\alpha} = \frac{1}{\gamma(N+1)}\left(A\frac{dS}{d\alpha} - 1\right) = \frac{1}{\gamma y)}\left((AS-\alpha) + \alpha - y\right)$$

Substitsuting in y we have

$$\frac{dD}{d\alpha} \propto -[(AS-\alpha)(\eta-1) - xAS]$$

hence for $\frac{dD}{d\alpha} < 0$ from the above it must be that

$$\eta - 1 > \frac{AS(2\beta p(S) - 1)}{(AS-\alpha)}(N+1). \tag{30}$$

Thus for sufficiently high η this condition will always be satisfied.
Thus, we have

$$\frac{dD}{d\alpha} = \frac{A\frac{dS}{d\alpha} - 1}{\gamma(N+1)} = \begin{cases} > 0 & \eta \leq 1 \\ < 0 & \eta \text{ large ie satisfying (28) and (30)} \\ \text{ambig} & \text{else} \end{cases} \tag{31}$$

In other words assuming that $\frac{dS}{d\alpha} > 0$, we need η sufficiently large (larger than needed above) so that the adjustment in risk-taking doesn't drive the adjustment in lending.

In conclusion we have shown that for sufficiently large η (ie sufficiently high sensitivity of the probability of success to the degree of risk taking S) monetary policy increases risk-taking and reduces lending. While the risk-taking result should hold for a wide range of parameters with $\eta > 1$ (since what was proven was a sufficient condition), the negative effect on lending requires a somewhat stronger restriction on the level of η.

First-order effect of competition

Risk-taking:
Using the FOC of S derived above and total differentiating wrt to N we have

$$[-\eta S^{\eta-2}\widetilde{den}]dS + p'(S)(-\frac{R}{N+1})dN = 0$$

Re-arranging and simplifying we have

$$\frac{dS}{dN} = \frac{RS}{(N+1)\widetilde{den}}.$$

Thus, the comparative static for risk-taking to competition will always share the same sign as that of monetary policy. In other words, for sufficiently large η we have that just as with contractionary monetary policy, risk-taking increases with competition, $\frac{dS}{dN} > 0$.

Lending:
Now computing for lending:

$$\frac{dD}{dN} = \frac{1}{\gamma(N+1)}\left(A\frac{dS}{dN} - R\right)$$

using the above

$$= \frac{R}{\gamma(N+1)}\left(\frac{AS}{(N+1)\widetilde{den}} - 1\right)$$

Then using the definition of $\widetilde{den}$ and simplifying

$$\frac{dD}{dN} < 0 \iff (AS - \alpha)(\eta - 1) - xAS > 0$$

which is the exact same condition as we obtained for the earlier comparative static for lending.

That is, for η sufficiently large we have more competition implies less lending, $\frac{dD}{dN} < 0$, while for sufficiently low η this condition is negative (e.g. $\eta \leq 1$ it is immediate).

Cross-partials of competition and monetary policy

Risk-taking:

Differentiating $\frac{dS}{d\alpha}$ wrt N, and letting $y = (N+1)\widetilde{den}$ we have

$$\frac{d^2S}{d\alpha dN} = \frac{1}{y^2}\left[\frac{dS}{dN}y - S\frac{dy}{dN}\right]$$

Now by definition of $y = (AS-\alpha)(\eta-1) + (1-x)AS$, and so

$$\frac{dy}{dN} = A\frac{dS}{dN}(\eta - x) + AS(-\frac{dx}{dN}).$$

Thus we have

$$\frac{d^2S}{d\alpha dN} = \frac{1}{y^2}\left[y\frac{dS}{dN} - S\left(A(\eta-x)\frac{dS}{dN} - AS\frac{dx}{dN}\right)\right]$$

Re-arranging

$$\frac{d^2S}{d\alpha dN} = \frac{\frac{dS}{dN}}{y^2}\left[y - AS\left((\eta - x) - \frac{S}{\frac{dS}{dN}}\frac{dx}{dN}\right)\right]$$

and simplifying

$$\frac{d^2S}{d\alpha dN} = \frac{\frac{dS}{dN}}{y^2}\left[-\alpha(\eta-1) + \left(\frac{AS^2}{\frac{dS}{dN}}\frac{dx}{dN}\right)\right]$$

Assuming that $\widetilde{den} > 0$, $\eta > 1$ so that $\frac{dS}{dN} > 0$ then in order for $\frac{d^2S}{d\alpha dN} < 0$ it is sufficient for $\frac{dx}{dN} < 0$.

By definition of $x = (2\beta p(s) - 1)(N+1)$, we have

$$\frac{dx}{dN} = 2\beta p'(S)(N+1)\frac{dS}{dN} + \frac{x}{N+1}.$$

using $\frac{dS}{dN}$ we have

$$\frac{dx}{dN} = \frac{1}{y}\left(2\beta p'(S)S(AS-\alpha) + \frac{x}{N+1}y\right).$$

Again plugging in y and x we have

$$\frac{dx}{dN} = \frac{1}{y}\left[\left(2\beta p'(S)S + \frac{x}{N+1}(\eta-1)\right)(AS-\alpha) + \frac{x}{N+1}(1-x)AS\right]$$

Assuming $1-x<0$ and $\widetilde{den} > 0$,[28] it is sufficient for $\frac{dx}{dN} < 0$ if $\Big(..\Big) < 0$.

[28]Notice that $1-x<0$ for any $N \geq 1$ if $p(S) \geq \frac{1}{2\beta(N+1)} = .2632$ which holds across all of our calibrations.

Collecting terms this corresponds to $(-2\beta S^{\eta}+2\beta p(S)-1)\eta<\frac{x}{N+1}$. Finally, noting that this condition trivially holds if the LHS bracket is negative, replacing $S^{\eta}=1-p(S)$ and solving for $p(S)$ such that the LHS is in fact negative we get the sufficient condition

$$p(S)<\frac{1+2\beta}{4\beta}$$

using our calibration of $\beta=.95$ the RHS is $=.763$ while with our baseline results $p(S)=.71$ and so our baseline calibration falls under this region.

In summary we have shown that

$$\frac{1}{4\beta}<p(S)<\frac{1+2\beta}{4\beta},\widetilde{den}>0 \quad \Rightarrow \quad \frac{d^2S}{d\alpha dN}<0 \tag{32}$$

that is monetary policy has a smaller effect on risk taking for small banks / more competitive banks than larger/less competitive within this range. By inspecting the proof, the range of parameters in which this comparative static will hold is likely substantially larger than the set characterized.

Lending

Given the above, the cross-partial for loans is much simpler to characterize. By direct computation,

$$\frac{d^2D}{dNd\alpha}=\frac{1}{\gamma(N+1)}\left[A\frac{d^2S}{dNd\alpha}+\frac{dD}{d\alpha}\frac{1}{N+1}\right].$$

Under the assumptions that give $\frac{d^2S}{dNd\alpha}<0$, $\frac{dD}{d\alpha}<0$ we then have the Kasyap-Stein result

$$\frac{d^2D}{dNd\alpha}<0.$$

In other words, lending will contract with contractionary monetary policy and will contract by more for more competitive banks than less competitive.

Summary of comparative statics

In summary, we have shown that under the conditions (28), (30) and (32), which includes our baseline parameterization, the following comparative statics hold:

Monetary policy:

$$\frac{dS}{d\alpha} = \frac{S}{(N+1)\widetilde{den}} > 0$$

$$\frac{dD}{d\alpha} = \frac{A\frac{dS}{d\alpha} - 1}{\gamma(N+1)} < 0$$

Competition

$$\frac{dS}{dN} = \frac{RS}{(N+1)\widetilde{den}} > 0$$

$$\frac{dD}{dN} = \frac{R}{\gamma(N+1)}\left(\frac{AS}{(N+1)\widetilde{den}} - 1\right) < 0$$

Monetary policy x competition

$$\frac{d^2S}{d\alpha dN} < 0$$

$$\frac{d^2D}{d\alpha dN} = \frac{1}{\gamma(N+1)}\left[A\frac{d^2S}{dNd\alpha} + \frac{dD}{d\alpha}\frac{1}{N+1}\right] < 0$$

In other words, contractionary monetary policy and competition have similar qualitative effects on individual bank risk-taking and lending. That is an increase in either will induce more risk-taking and less lending. Finally, contractionary monetary policy has a larger effect on lending in competitive environments but a reduced effect on risk-taking.

These results depend on a relatively high sensitivity of the probability of success on risk-exposure S. Suppose in contrast that $\eta \to 1$, then $\frac{dS}{d\alpha}$ and $\frac{dS}{dN}$ switch from positive to negative, $\frac{dD}{d\alpha}$ and $\frac{dD}{dN}$ remain negative.

Deriving sufficient bounds on sign of $\widetilde{den}$

We showed that

$$\widetilde{den} = R(\eta - 1) + (1 - x)[R + \frac{\alpha}{N+1}]$$

and that the sign of many of the comparative statics depend on the sign of $\widetilde{den}$ / the magnitude. Here we derive sufficient conditions that assure $\widetilde{den} > 0$ or negative

Sufficient conditions for $\widetilde{den} > 0$

Note if $|x| < 1$ or $x < 0$ then trivially $\widetilde{den} > 0$.[29] Suppose this is not the case, (ie $1 - x < 0$) then

$$\begin{aligned}
\widetilde{den} &\geq \min(\alpha, R)\left[(\eta - 1) + (1 - x)\left(\frac{N+2}{N+1}\right)\right] \\
&> \min(\alpha, R)\left[(\eta - 1) + (\frac{N+1}{N+2} - x)\left(\frac{N+2}{N+1}\right)\right] \\
&= \min(\alpha, R)\left[\eta - x\left(\frac{N+2}{N+1}\right)\right]
\end{aligned}$$

Finally using the definition of x, we get the sufficient condition

$$\eta \geq (2\beta p(S) - 1)(N + 2).^{30} \tag{33}$$

Sufficient conditions for $\widetilde{den} < 0$

Now on the other hand, we will pin down sufficient conditions for the converse.

$$\widetilde{den} \leq \max(\alpha, R)\left[(\eta - 1) + (1 - x)\left(\frac{N+2}{N+1}\right)\right]$$

Assuming $\eta > 2$ (we have $\eta\frac{N+1}{N+2} > 1$) and so

$$< \max(\alpha, R)\left[(\eta - 1) + \eta - x\left(\frac{N+2}{N+1}\right)\right]$$

Solving for η which makes the interior negative yields

[29] Notice that $x < 0$ corresponds to $p(S) < \frac{1}{2\beta} = .5263$ using $\beta = .95$. This is not satisfied under the baseline calibration.

[30] Plugging in the baseline parameters $\eta = 4$, $N = 3$ and $\beta = .95$ and the result $p(S) = .71$ we see that this condition is satisfied.

$$\eta \leq \frac{1 + (2\beta p(s) - 1)(N + 2)}{2} \tag{34}$$

We have thus given the sufficient conditions for when $dS/d\alpha$ is positive and negative.