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.

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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 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.

Our paper contributes to the literature on competition and stability in several ways.[3] First, we build on earlier theoretical papers on competition and stability (such as Allen and Gale [6], Boyd and DeNicolo [14], and Martinez-Miera and Repullo [44]) by: (a) endogenizing bank market structure so that banks enter and exit in the long-run depending on expected profits, (b) incorporating leverage requirements and monetary policy into our dynamic model of competition and stability, and (c) allowing for agency frictions between bank owners and managers. 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. 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 [20], [22] and Egan, Hortascu, and Matvos [27].

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 ([39], [40], [41], hereafter JLL).

We find there is a *competition-stability* tradeoff: the removal of regulatory impediments to competition increases the fragility of the banking system. By squeezing bank profit margins and lowering franchise values, competition boosts risk as banks increase lending to riskier firms. The other side of the tradeoff also holds: competition boosts market efficiency measured by interest margins. Regulatory reforms that facilitate competition (a) lower interest margins as banks compete for clients on both sides of the balance sheet, (b) spur financial

[1] In discussing the Dodd-Frank Act, Federal Reserve Governor Tarullo [51] 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. From this *competition-stability* perspective, therefore, policymakers should focus on identifying and reducing impediments to competition.

[3] Vives [52] provides a comprehensive review of this literature.

innovations that improve banking services, and (c) induce banks to become more transparent as they compete in capital markets to issue securities. These last findings - that competition fosters innovation and transparency - can mitigate the long-run impact of competition on fragility, but they do not reverse the result that a regulatory-induced intensification of competition has a net, negative impact on banking system stability. Consistent with the *competition-fragility* view, these new findings highlight the value of research that helps policymakers choose policies that maximize the efficiency benefits, while minimizing the fragility costs, of competition.

The model and empirical findings also suggest that policymakers can mitigate the fragility repercussions of lowering barriers to competition by enhancing bank governance and tightening leverage requirements. With respect to improving bank governance, we mean regulatory policies that either directly or indirectly encourage 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 do not examine any particular regulatory policy associated with executive incentives. Rather, we explore the impact of regulatory policies in general that enhance the governance of banks.

Our analysis indicates that policies that improve bank governance by incentivizing executives to focus more on the long-run value of the bank to reduce excessive risk-taking (that is, risk taking that exceeds the level chosen by a social planner). Moreover, policies that improve bank governance tend to lessen traditional principal-agent frictions between owners and managers, boosting banking system efficiency (lowering measured interest margins and lowering risk taking closer to that chosen by the social planner). These findings advertise the win-win-win effects of regulatory reforms that improve bank governance: They boost bank stability; they enhance bank efficiency; and they mitigate the risk-increasing effects of regulatory reforms that intensify bank competition.

With respect to leverage requirements, our research suggests that tightening leverage requirements (i.e., raising non-risk-based capital requirements) reduces bank risk taking. The intuition is as follows. If tightening leverage requirements increases the amount of personal wealth that owners have at risk, then owners will have stronger incentives to constrain excessive bank risk taking. Moreover, we find that tightening leverage requirements has a bigger risk-reducing effect in well governed banks. That is, if a tightening of leverage requirements induces owners to want the bank to take less risk, then the actual reduction in risk will be larger when bank executives act in the long-term interests of the owners. The opposite also holds. If executives don't care about the long-term interests of shareholders (the case in poorly governed banks), then leverage requirements that induce shareholders to want less risk will have little effect on actual risk taking.

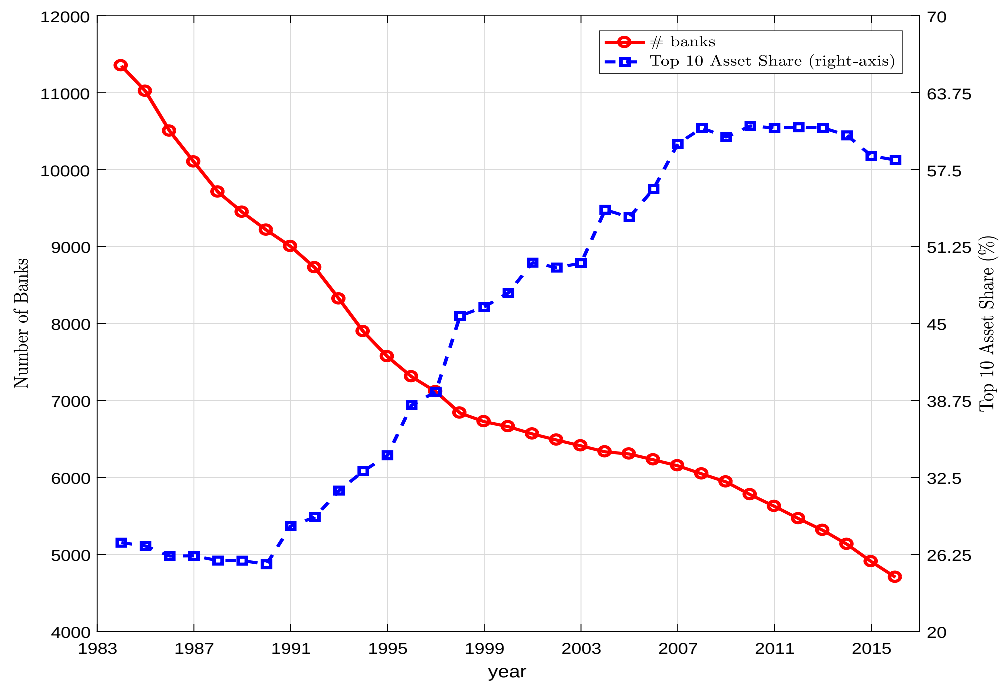
There are two bottom-line policy messages on competition, leverage requirements, and bank governance. First, policymakers can mitigate the fragility repercussions of lowering barriers to competition by tightening leverage requirements and enhancing bank governance. Thus, policymakers can get the efficiency benefits of intensifying competition without increasing banking system fragility.

Second, we show that capital requirements and governance are inextricably linked. To see this, consider two extreme examples: (1) a "bank' that is financed only with equity (100% capital requirements), has only small shareholders who cannot effectively govern the bank's manager who is compensated with an option contract that provides a big bonus when bank returns are high but does not materially penalize the manager for poor performance and (2) a bank that is highly levered and has a single owner, who is also the only manager, so that there are none of the standard governance frictions between owners and managers. Even though the first bank is fully financed with equity, it might take excessive risk because of the incentives of the manager and the governance frictions within the bank. Similarly, even though the second bank does not have an owner-manager governance problem, the owner might induce the bank to take excessive risk due to limited liability and government insurance of the bank's debt holders. Thus, capital requirements and governance combine to shape bank lending and risk. Both in the model and the data we show that regulatory reforms which encourage bank executives to focus on the long-run value of the bank increase efficiency, reduce fragility, and amplify the effectiveness of capital requirements in reducing excessive risk taking.

Further, we provide new findings on how monetary policy affects bank risk taking and lending both in the short and long run. We find that monetary policy may have a bigger short run effect on lending in more competitive banking systems. In more competitive banking systems with narrower profit margins, contractionary monetary policy triggers a sharper balance sheet response than in banking systems in which banks have large profit margins to cushion the effects of monetary policy on lending. Although policy analysts typically ignore the structure of the banking system in evaluating the effects of monetary policy, our analysis emphasizes the value of accounting for the competitiveness of the banking system in assessing the monetary transmission mechanism. Finally, we show how monetary policy may actually have a long run impact on bank market structure itself.

As Figure 1 makes clear, the number of commercial banks in the U.S. has fallen dramatically while the asset market share of the top 10 banks has doubled. While concentration is an imperfect measure of competition (something our empirical analysis attempts to account for), rising market shares suggest the value of developing tractable quantitative models which incorporate imperfect competition in the banking industry as an alternative to the perfectly competitive assumption in most DSGE models. This paper is an attempt to fill that gap.

Figure 1: U.S. Bank Numbers and Concentration



Note: Number of Banks refers to the number of bank holding companies. Top 10 Asset share refers to the share of total assets in the hands of the top 10 banks in the asset distribution.

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 policies in both the short and long run in Section 3. Specifically, subsection 3.2 takes policy changes as exogenous while subsection 3.1 endogenizes the policy choice. Further, we study the robustness of our model in subsection 3.3. Section 4 tests some of these predictions using detailed U.S. data.

2 Model

Our model generalizes the work of Allen and Gale [6], Boyd and DeNicolo [14], and Martinez-Miera and Repullo [44] 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) Endogenous Market Structure, and (iv) Optimal Regulatory and Monetary Policy. Related quantitative theory models include Egan, Hortascu, and Matvos [27], who focus on imperfect competition in the deposit market, and Corbae and D'Erasmo ([20],[21],[22]), who focus on imperfect competition in the loan market.

These quantitative models introduce idiosyncratic differences between banks which requires tracking the distribution of bank characteristics over time. Since we focus on symmetric equilibria with imperfect competition in the deposit market, we simply need to keep track of the number of identical banks.

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 [20], [22] and Egan, Hortascu, and Matvos [27].

Our results on the effectiveness of monetary policy across different market structures is related to work by Kashyap and Stein [43]. In particular, the idea in their paper that small banks face higher external financing costs than big banks is consistent with higher funding costs in a more competitive industry in our model. Despite the richness of predictions from the model, it amounts to solving 3 equations in 3 unknowns.

Solving the bank's dynamic optimization problem allows us to connect to the literature on bank charter values. 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. Endogenous market structure arises out of a "free entry" condition whereby shareholders make an initial equity injection to cover entry costs pinning down the equilibrium number of banks. Finally, we provide regulatory tools (modeled as control over bank entry, governance, and leverage constraints) and monetary tools (modeled as the marginal cost of bank funding) for a policymaker to minimize both the deviation of decentralized risk taking and expected output from their efficient levels.

Since market structure is endogenous in our model, a change in policy can affect competition. Analogous to regulatory arbitrage (where a change in policy affects competition from shadow banks *across* the financial system), here a change in policy can affect competition *within* the banking system. This allows us to avoid the Lucas critique within the banking system.

One of the important insights from the model links the executive's choice of the riskiness of the bank's loan portfolio to interest margins and agency weighted leverage, both of which depend on banking industry concentration. We contrast the market predictions for risk taking with the efficient level of risk taking for our environment and ask whether a policymaker may be able to implement the efficient levels through regulatory or monetary policies. This allows us to focus on the competition, stability, and efficiency properties of the banking industry.

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. 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 $\eta \geq 1$. If $Z \geq 0$ units are invested in the technology, then expected output is $p(S) \cdot S \cdot A \cdot Z$. The (opportunity) cost of the input is given by $\widetilde{\gamma} \cdot Z^2$, which generates 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 as there are no seasoned equity injections (i.e., for bank i, $L_i = D_i$).[4] For purely technical reasons, we assume that for arbitrarily large N, the cost of entry becomes infinity.[5] The total supply of deposits is given by $Z = \sum_{i=1}^{N} D_i$ with inverse deposit supply function given by $r_D(Z) = \gamma Z$. 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 $\frac{D_i}{E_i} \leq \lambda$. The manager discounts cash flows at rate β. There is deposit insurance, for which bank i pays $\widehat{\alpha}$ per deposit when the bank is solvent. Limited liability implies that if a bank is insolvent, it does not pay its depositors.[6] More generally, we introduce a parameter α to capture *both* this deposit insurance cost as well as a government policy parameter controlling the marginal cost of obtaining funds (which may be interpreted as a Fed Funds rate). 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 $u(c_E) = \psi_E c_E$. For simplicity we take $\psi_M = f^{-1}$ 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

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

An interior solution to (1) is given by

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

At the allocation in (2), we have

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

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.

[4] 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 $= D_i + E_i$.

[5] That is, for $N <= \bar{N}$ (arbitrarily large) the entry cost is κ while for $N > \bar{N}$ the entry cost is infinity, which imposes a finite upper bound on N.

[6] Here, as in the Allen and Gale [6] and Boyd and DeNicolo [14] environments, the entire portfolio either succeeds or fails for simplicity. The general case where there are aggregate and idiosyncratic shocks is considered in Martinez-Miera and Repullo [44].

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 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 number N of incumbent banks as given, in each period the manager of incumbent bank i chooses a level of risk taking S_i 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., payments proportional to the deposit insurance "tax" $\widehat{\alpha}$ by solvent banks and external funds F must cover deposit insurance on failing banks). We assume that an individual incumbent bank does not internalize that it may affect the "tax"it pays to the deposit insurance fund.[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 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.

[7]Davila and Walther [23] examine a model in which big banks internalize their behavior on government bailout policies.

2.3.1 Bank Problem

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

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

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]

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

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]

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

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

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.

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

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

[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 [26]), we follow a traditional static-dynamic breakdown whereby a price or quantity decision affects static profitability but not the dynamics of the entire industry.

that shareholders with discount rate δ will inject equity to fund bank i entry provided

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

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

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 $\frac{r_D'(Z)}{N} = \frac{\gamma}{N}$.[11]

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

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

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.

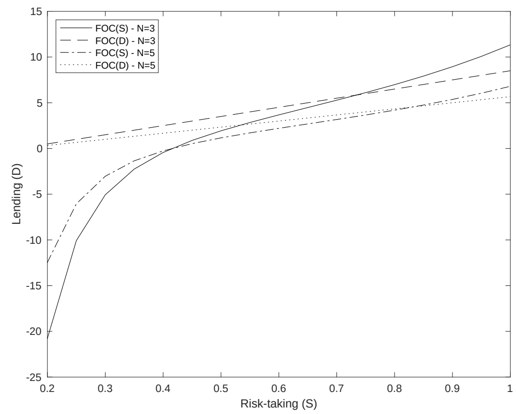
We illustrate the two first order conditions (6) and (7) in a symmetric equilibrium, which are functions of market structure N, graphically in the next series of figures. In particular, Figure 2a provides the two first order conditions for two possible market structures (drawn for our calibrated parameter values) when the leverage constraint is non-binding (i.e. $\mu = 0$). As evident in Figure 2a the level of risk-taking S rises and individual bank lending $D = L$ falls in the more competitive market structure $N = 5$ relative to our benchmark $N = 3$.

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 $\lambda = 14.83$, 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. $\beta = 0.95$ for managers while $\delta = 0.99$ 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.

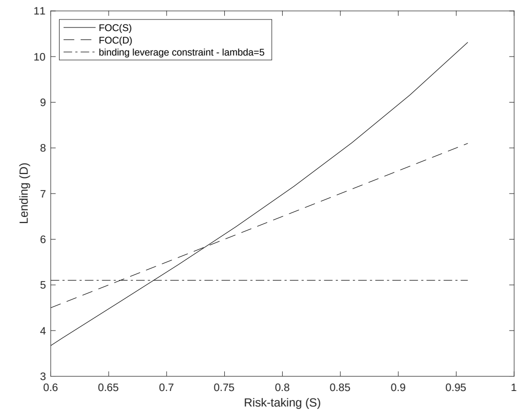
Finally, in Figure 3b, we illustrate how contractionary policy (exogenous increases in the marginal cost of funding to banks captured by an increase in α affect risk taking and lending when $N = 3$. In particular, we raise α from 0.03 in our benchmark to 0.05. Figure 3b makes clear that as contractionary monetary policy raises the cost of funding loans, lending drops but risk taking rises in the short run.

Figure 2: Comparative statics



(a) Risk Taking and Lending FOCs Across Market Structure

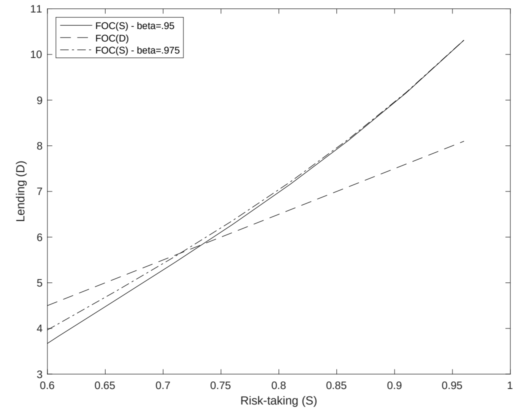
Notes: FOC(S)-N and FOC(D)-N denote first order conditions for S and D for a given market structure N.



(b) Leverage Unconstrained versus Constrained FOCs

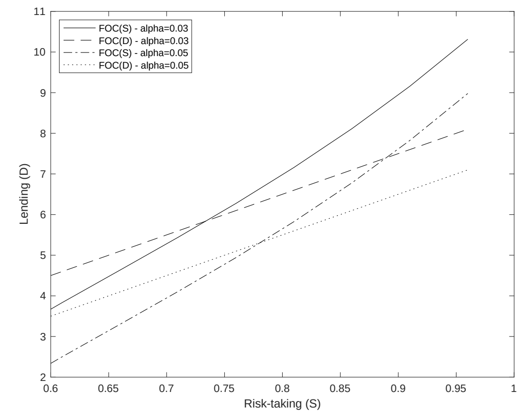
Notes: FOC(S) and FOC(D) denote first order conditions for S and D for N=3 when $\lambda = 14.83$. binding leverage constraint - $\lambda = 5$ pins down D.

Figure 3: Comparative statics



(a) Agency Conflict Effects on FOCs

Notes: FOC(S)-beta and FOC(D) denote first order conditions for S and D with N=3 across $\beta = 0.95$ benchmark versus $\beta = \delta = 0.975$.



(b) Contractionary Policy Effects on FOCs

Notes: FOC(S)-alpha and FOC(D)-alpha denote first order conditions for S and D with N=3 across $\alpha = 0.03$ benchmark versus $\alpha = 0.05$.

2.3.2 Government Budget Constraint

Condition (c) requires that the expected inflows to the deposit insurance fund equal expected outflows, so that

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

The left hand side of (15) represents the flows into the fund from solvent bank being charged $\widehat{\alpha}$ per unit of funds and outside funding sources F (e.g. tax revenues) to cover the payments to depositors at insolvent banks on the right hand side of (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 $\Theta = (\kappa, \beta, \alpha, \lambda)$ to minimize the weighted distance between the decentralized level of risk taking from the planner's level (with weight $1 - \phi$) as well as deviations in expected output (with weight ϕ). 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 symmetric recursive Cournot equilibrum 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 Ramsey equilibrium is defined by the government choosing among Θ to maximize 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 S and 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, 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

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

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 $V_{\Theta'}(N') <> V_{\Theta'}(N)$).

2.4 Calibration

Next we calibrate the model to U.S. data that will form the basis of our empirical work.[12] The model has two sets of parameters. One set are those associated with preferences and technologies $(A, \widetilde{\gamma}, \delta, \eta)$. The second set are those associated with government policy $(\kappa, \beta, \lambda, \alpha)$.

The benchmark model we calibrate assumes (a) there are agency conflicts and (b) leverage requirements are non-binding. Taking a model period to be one year, we set $\delta = 0.975$. Since the leverage constraint is non-binding, we set λ arbitrarily large. We consider a monetary environment where the marginal cost of a unit of external funds is set at $\alpha = 0.03$ which includes an FDIC charge to solvent banks of $\widehat{\alpha} = 1\%$.

The remaining parameters are chosen to match summary statistic data in Table 2 of Jiang, Levine, and Liang [40] along with new calculations. In particular, mean bank concentration of 0.33 implies we target $N = 3$.[13] 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 [45] model normalized by the gross return on assets to give a scale-free measure of bank profit volatility which is 0.067. 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 $log(D) = 22.46$.[14] 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.

Table 1: Data and Benchmark Model Moments

	Data	**Model**
Concentration	0.330	0.333
ROA	0.040	0.021
cv(ROA)	0.067	0.013
D/E	14.830	14.888
log(Deposits)	22.466	22.489

Table 2: Benchmark Parameters

	values
β	0.950
δ	0.975
α	0.030
A	0.200
η	4.000
$\tilde{\gamma}$	4×10^{-12}
κ^*	392.473

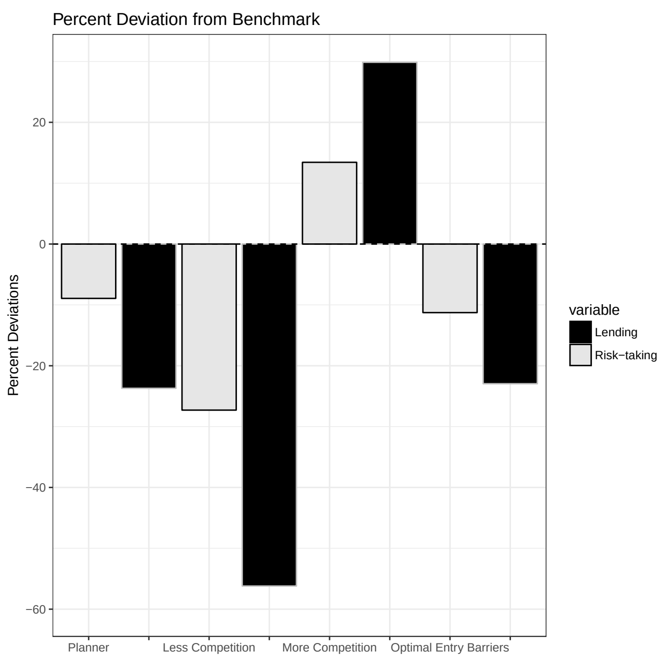
Left Table: * In millions. Right Table: Parameters above the line are chosen outside the model. Parameters below are chosen inside the model.

[12]The simple matlab code to run the model is described in Appendix E and can be found on the authors' websites.

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

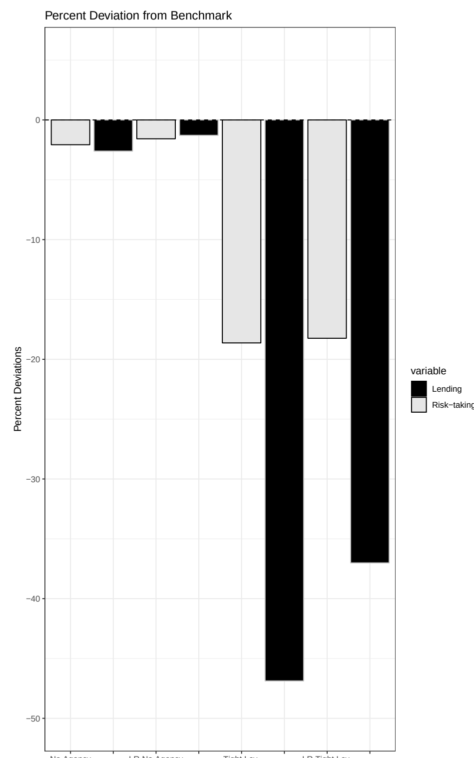
[14]It can be shown that $\widetilde{\gamma}$ is uniquely identified by this moment.

Figure 4: Risk-Taking and Aggregate Lending Across Regulatory Policy Interventions



(a) Varying Competition

Percent deviations from the benchmark (N=3), Social Planner, Less Competitive (N=1), More Competitive (N=5), Optimal Policy (N=2.1). See Table A1 for details.



(b) SR vs LR regulatory counterfactuals

Percent deviations from the benchmark. No agency ($\delta = \beta = .975$), Tight Leverage ($\lambda = 5$). See Table A2 for details.

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 4a 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.

What are the predictions from the changes in market structure depicted in Figure 4a (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 $N = 1$.

First, there is a monotonic relation between competition N and risk taking S. That is, risk taking in a less competitive ($N = 1$) economy is 27% lower than the benchmark while risk taking is 13% higher in a more competitive ($N = 5$) economy. These choices translate into a 30% higher probability of success in the less competitive economy and a 27% lower probability of success in the more competitive economy.

Second, relative to the social planner's choice of risk taking, despite the agency problems and limited liability, banks in the less competitive economy actually take less risk 27% than the social planner choice which is only 9% lower than the benchmark. That is, too little competition may generate inefficiently low risk taking. 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. The social planner chooses a level of Z which is 24% lower than the benchmark and the more competitive economy, where $N = 5$, has 30% higher investment than the benchmark. The less competitive economy, where $N = 1$, has 56% lower investment than the benchmark and "under-invests" even relative to the social planner. Investment depends not only on then number of banks but also the "size" (D) of each bank. We see that banks are 31% larger in the less competitive environment and 22% smaller in the more competitive environment than the benchmark.

Fourth, leverage is monotonically increasing in the degree of competition. That is, leverage is 80% lower in the less competitive economy than in the benchmark while banks in the more competitive economy choose 181% higher leverage than the benchmark.

Fifth, interest margins ($R \equiv A \cdot S - (r_D(Z) + \alpha)$) are monotonically decreasing in the level of competition. That is, interest margins are 31% higher in the less competitive economy while they drop by 22% relative to the benchmark when $N = 5$. Expected static (π) and long run profits (κ=E) are decreasing in the level of competition.

Sixth, 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 less competitive ($N = 1$) and the benchmark ($N = 3$) market structures. To analyze how policy makers would choose the optimal entry barriers, 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. 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 4a and Table A1 that by choosing a higher entry barrier (κ rises by 124% inducing the "number" of banks to fall to 2.1), the policy results in risk taking and investment which converge towards the efficient level chosen by the social planner.[15] Further, Table A1 makes clear that the optimal policy induces banks to take on much less leverage (i.e., 50% lower) than the benchmark. This completes the description of a "Ramsey" equilibrium 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) policies designed to eliminate agency conflicts (i.e., we increase the manager's discount factor $\beta = .95$ to that of the shareholders $\delta = .975$), (b) impose binding leverage constraints (i.e., we drop λ from roughly 15 (consistent with our benchmark data) to 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 $\alpha = 0.05$). In all cases, we assume $\zeta = 0.1$ so that it takes on average 10 years to transition to the new long run equilibrium associated with the policy change.

3.2.1 Regulatory Policy Counterfactuals

First, we analyze the short run impact of agency conflicts in bars 1 and 2 of Figure 4b (and column 2 of Table A2). Better governance policies that induce a manager to be less myopic induce less risk (S drops by 2% relative to the benchmark in the short run) resulting in a 3% increase in success probability. Less myopic managers "under-lend/under-invest" relative to the benchmark and take on less leverage (i.e., Z drops by 3% and D/E drops by 8%).

[15]For our benchmark calibration, these results are robust to setting $\phi = 1$, so that the policymaker has the same objective as the social planner.

Interest margins and short run profits drop by 3% and 2% respectively (because the manager takes on less risky lower return projects). However, the higher likelihood of success generates a longer stream of discounted profits so that the equity value of the bank rises (E rises by 6% and the manager's value V actually rises by 11%). The policy also decreases volatility of bank equity (i.e. the coefficient of variation of E drops by 6%). The decrease in lending outweighs the increase in success probability to generate 1% lower output but also a 12% lower coefficient of variation of output. The higher success probability leads the expected cost of funding bank failures to fall (F/Y drops by 17%).

Given that the governance change leads to higher long run profitability 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 given in bars 3 and 4 of Figure 4b (and column 3 of Table A2). The rise in entry leads to more competition (N is 3% higher), which in turn lowers the long run decrease in risk taking and aggregate lending as well as interest margins. The long run rise in success probability counteracts the drop in aggregate lending so that bank intermediated output is unchanged in the long run. The long run expected cost of funding bank failures falls (F/Y drops by 12%), but less so than in the short run.

Second, we analyze the impact of tightening leverage requirements (to a level which is binding relative to the unconstrained benchmark) in bars 5 and 6 of Figure 4b (and column 4 in Table A2). Tighter leverage requirements lead to less risk taking (S falls by 19% relative to the benchmark) resulting in a higher success probability ($p(S)$ rises by 23%). Tighter leverage constraints reduce lending/investment relative to the benchmark (Z falls by 47%). Thus, tighter leverage requirements drive the economy toward the risk and lending levels selected by the social planner. Interest margins increase by 47%. The drop in lending however leads to lower short run profitability but the increase in success probability leads to higher long run profitability (π drops by 4% while E rises 58%). The policy also decreases volatility of bank equity (i.e. the coefficient of variation of E drops by 40%). The decrease in lending greatly outweighs the increase in success probability to generate 47% lower intermediated output but also a 81% lower coefficient of variation of output. Tightening leverage generates a large decrease in the expected cost of funding bank failures (F/Y drops by over 115%).

Given that tighter leverage constraints lead to higher long run profitability 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 tighter leverage constraints is given in bars 7 and 8 of Figure 4b (and column 5 of Table A2). The rise in long run profits induces entry (N is 87% higher) means that D drops by 66% while Z drops 37% from the short run. There is also a slight difference in risk taking relative to the short run. Thus tightening leverage constraints leads to 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. For instance, a tightening of leverage constraints can be expected to alter the risk-taking of managers whose incentives are aligned to that of shareholders differently than those with significant agency frictions (due perhaps to lax governance). 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. However, if we restrict ourselves to relatively small agency conflicts, the interaction of tightening leverage (reducing λ) and decreasing agency conflicts (increasing β) will magnify the reduction in risk-taking. Denote $S(\lambda, \beta)$ to be the equilibrium risk-taking with leverage constraint λ and manager discount factor β holding all other parameters constant. Column 6 of Table A2 computes this counterfactual where both leverage constraints are tightened and agency conflicts are solved (i.e., setting $\lambda = 5$ and $\beta = 0.975$). Under our benchmark calibration, we find that the percentage change in risk-taking from tighter leverage requirements is $\Delta(S; \beta_L = 0.95) = \frac{S(\lambda_L,\beta_L)-S(\lambda_H,\beta_L)}{S(\lambda_H,\beta_L)} = \frac{0.5975-0.7343}{0.7343} = -18.6\%$ while in an environment where there is no agency conflict the percentage change in risk-taking induced by the tightening of leverage requirements is $\Delta(S; \beta_H = .975) = \frac{S(\lambda_L,\beta_H)-S(\lambda_H,\beta_H)}{S(\lambda_H,\beta_H)} = \frac{0.5811-0.7191}{0.7191} = -19.2\%$. Thus we find a 0.6% higher interaction effect when agency conflicts are mitigated than in the baseline case.[16] This finding motivates our empirical analysis in Section 4.4.

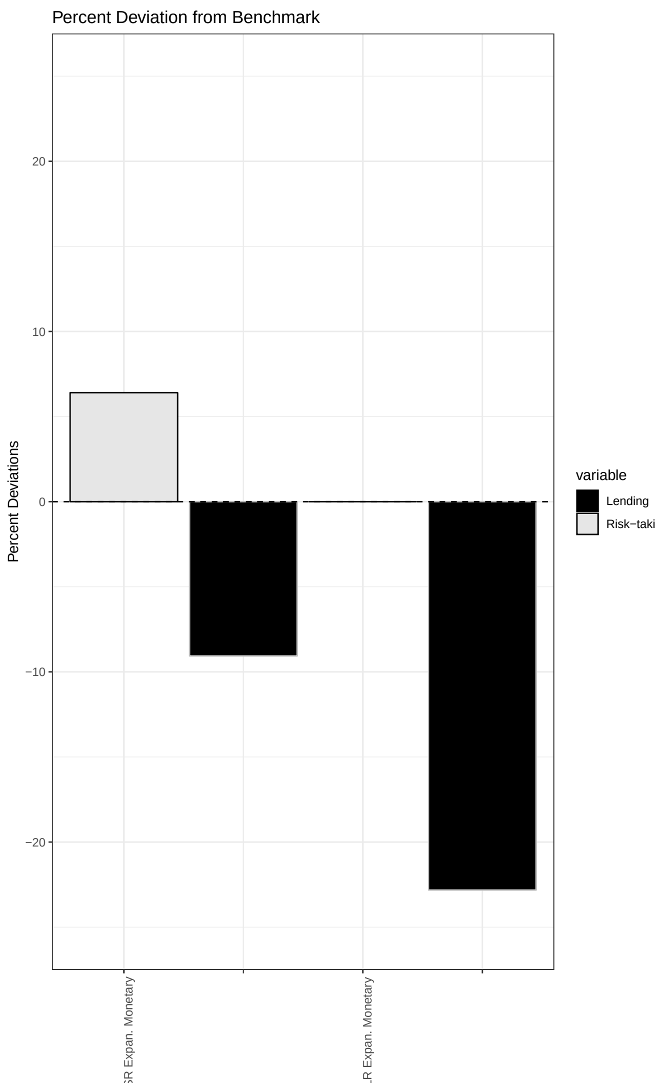
3.2.2 Monetary Transmission and Competition

Next we analyze the impact of a policy which increases the marginal cost of funds α from 0.03 in the benchmark to 0.05 in Figure 5a (and columns 2 and 3 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 fixed at the benchmark), a rise in the marginal cost of funds leads banks to take on more risk (S rises by 6% relative to the benchmark) resulting in a lower success probability ($p(S)$ falls by 12%). Contractionary monetary policy leads to less aggregate lending/investment relative to the benchmark (Z decreases by 9%). While individual bank lending falls, it falls by less than equity values so that leverage rises at the individual bank level (D/E rises by 57%). Interest margins, short run profits, and the equity value of the bank all fall (R falls by 9% and E falls by 42%) while the coefficient of variation of equity value rises by 20%. The decrease in aggregate lending leads to lower intermediated output (Y falls by 14%) and higher coefficient of variation of output by 24%. The lower success probability and lower output leads the expected cost of funding bank failures to rise (F/Y almost doubles).

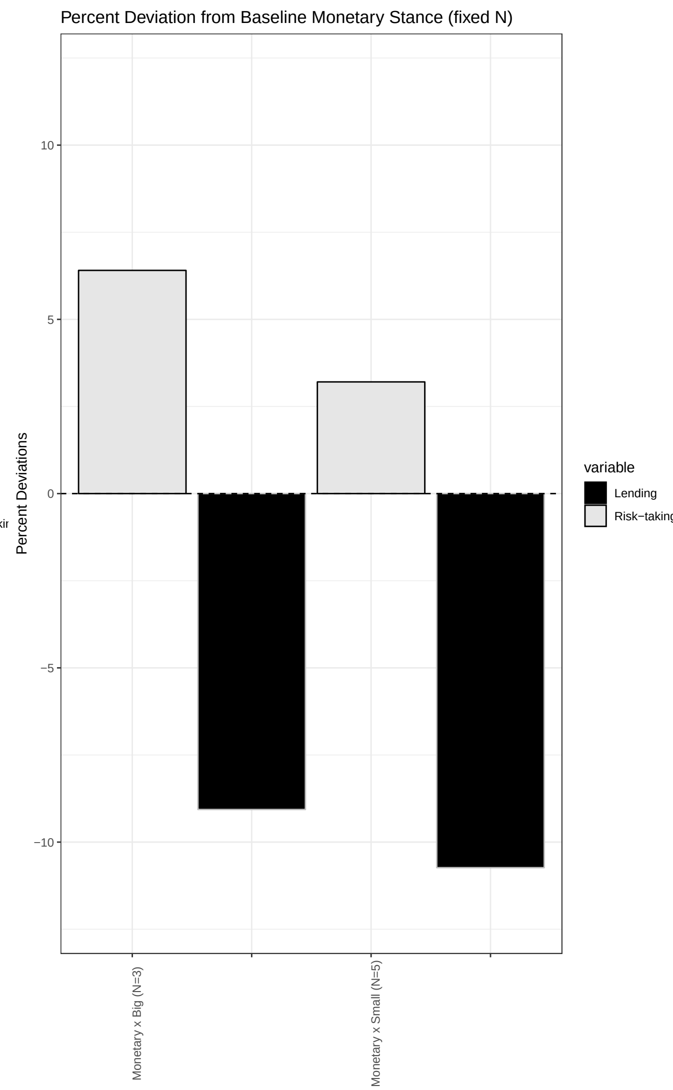
We now consider the long-run. In the short run, we established that if the Fed follows a contractionary monetary policy (increasing the Fed Funds rate resulting in a higher marginal cost of obtaining funding), then profitability falls. In the long run however, lower profitability decreases the incentive for bank entry thereby leading to less competition. In particular, the number of banks falls by 23%. 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). Thus, a contractionary monetary policy, for instance, could lead to short run instability but does not affect long run stability. Further, the short-run decrease in aggregate lending is magnified in the long-run (i.e., Z is 9% lower than the benchmark in the short run while it is 23% lower in the long run due to the change in

[16] That is, $\Delta(S; \beta_H = .975) - \Delta(S; \beta_L = 0.95) = -0.6$ and since the cross partial $\frac{\partial^2 S}{\partial \beta \partial \lambda}$ is for a rise in λ, we need to take -(-0.6).

Figure 5: Monetary Policy Interventions



(a) Short-Run vs. Long-Run Monetary policy



(b) Monetary policy across market concentration

Percent deviations from levels of same market size. See Table A3 for details.

market structure). In summary, the short run and long run impacts of contractionary policy on risk taking go in opposite directions so that there is no long run effect on risk taking. On the other hand, aggregate lending is decreased through the intensive margin (decreased D) in the short run but greatly through the extensive margin (decreased $N \cdot D$) in the long run. Decreased aggregate lending leads to a large decrease in intermediated output relative to the short run.

In Figure 5b (and columns 4 and 5 of Table A3 in the Appendix), we consider the impact of contractionary monetary policy in two different market structures. In particular, we ask what is the effect of increasing α to 0.05 from 0.03 in the benchmark ($N = 3$) market structure versus a more competitive economy ($N = 5$)? This is relevant for thinking about the monetary transmission mechanism that was studied in Kashyap and Stein [43]. They found that contractionary monetary policy lowered lending by smaller banks more than larger banks since it is more costly for smaller banks to get outside funding. Here we simply analyse whether contractionary monetary policy affects risk taking and lending more with smaller banks ($N = 5$) than with larger banks ($N = 3$).

The results confirm that our model is consistent with the results of Kashyap and Stein. In particular, in the short run smaller banks ($N = 5$) decrease their lending by 11% while larger banks ($N = 3$) decrease their lending by 9% in response to a rise in α from 0.03 to 0.05. While the monetary transmission mechanism is stronger in less concentrated markets, the short run effect of contractionary policy on risk taking is stronger in more concentrated industries (i.e., S rises by 6% with big banks while it rises by 3% with small banks). While there are no long run changes in risk taking relative to their respective benchmarks, the more competitive industry sees a larger decrease in aggregate lending relative to its benchmark than the less competitive industry in the long run.

3.3 Robustness

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_i) 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.

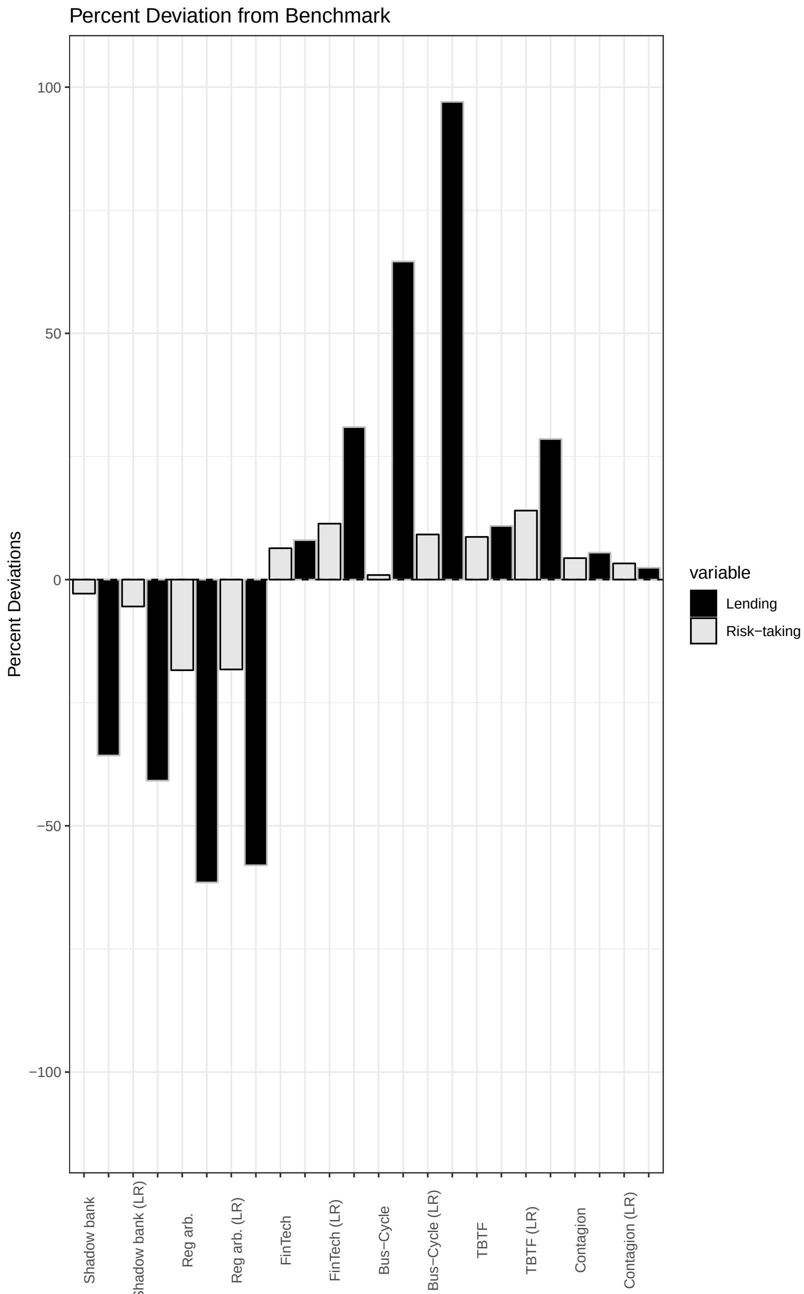
The problem of an incumbent manager is now to choose $S_i \in [0, 1]$ and $D_i \leq \lambda E_i$ to solve

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

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:

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

Figure 6: Robustness



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 $-p'(S_i) \cdot \beta \cdot V_i(N') \cdot (1 - b\theta_M)$ 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

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

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

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

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 [36], 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.[17] We choose $b = 0.8$ to match this value. We provide the results in the last bars of Figure 6 and columns 1 and 2 in Table A5.

In the short run, TBTF induces an increase in risk taking (S rises by 9%) as well as bank lending (D rises by 11%). The increase in risk taking rises more than the increased cost of obtaining funding so that interest margins, short run and long run profitability rise (i.e. R rises by 11%, π rises by 3%, and E rises by 134%). The large rise in government supported equity relative to the rise in deposit financing actually leads to a decrease in leverage (D/E falls by 53%). [18] The increase in lending offsets the lower probability of success to generate an increase in intermediated output as well as an increase in the expected cost of bailouts (Y rises by 1% while F/Y rises 100%). Not surprisingly, the coefficient of variation in output and equity values rise by 68% and 29% respectively.

In the long run, the increase in profitability induces entry and a more competitive banking sector (N rises by 52%). This induces even more risk taking and "over" lending (S rises by 14% and Z rises by 29%). While interest margins rose in the short run, they fall in the long run with the increase in competition (R decreases by 15%) as does short run profits (π drops

[17] 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].

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

by 48%). The impacts on output and expected bailout costs rise even more in the long run, as do the coefficients of variation.

One may ask if there is any degree of competition (i.e. N) such that bailouts are actually beneficial? Recall from Section 3.1 that a monopolistic banking sector induces too little risk taking and lending even relative to the social planner in order to maintain their high charter value (i.e. S and Z for $N = 1$ are 27% and 56% lower than the benchmark while S and Z chosen by the planner are 9% and 24% lower than the benchmark in Table A1). Hence, as we have seen a policy like TBTF which induces more risk taking and lending may actually be beneficial in very concentrated market structures. To this end, we find that if we introduce TBTF with $b = 1$ and $\theta_E = \theta_M = 0.72$, the monopolist bank chooses to decrease risk taking and lending closer to what the social planner chooses (i.e. S is 4% lower than the benchmark and Z is 19% lower than the benchmark).

3.3.2 Rise of Shadow Banks

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). 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 $r_D(Z) = \gamma Z$. 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 6 and columns 2 and 3 of Table A4. It is clear from the results that competition with other nonbank sources for funding decreases individual and aggregate bank lending (i.e. D and Z decrease by 36% since N is fixed) but does not impact risk taking and interest margins in the short run. Interest margins, short run profits, and equity values all drop (R drops by 4% and E drops by 28%) as well as output.

In the long run, however, decreased profitability of the banking sector leads to less entry (N drops by 16%); that is, a smaller banking industry. Less competition in the banking industry induces incumbent banks to take even less risk and lower leverage (S drops by 5% and D/E drops by 29%). The decrease in competition leads to higher interest margins (R rises by 6%) but the drop in lending leads to lower short run profits (π falls by 18%). Intermediated output drops by 39% as does the coefficient of variation of output by 55% and coefficient of variation of bank equity by 14%.

3.3.3 Fintech

Here we consider the impact of a better screening 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 6 and Table A4.

In the short run, despite the fact that risk taking rises (S rises 6%), the success probability rises substantially ($p(S)$ rises 29% to 0.92). Lending increases (D rises by 8%). Interest margins and equity value rise (R by 8% and E jumps 33-fold). The coefficient of variation of equity drops by 53%. Given success probabilities rise, the cost of bailouts fall substantially (F/Y falls four-fold). Intermediated output rises by 48% and its coefficient of variation drops 67%.

The large rise in short run equity values induces long run entry. In particular, the number of banks doubles in the long run (N rises 104%). This competition induces smaller banks (i.e. D drops by 36% in the long run) but aggregate lending is still higher than the benchmark (Z rises 31%). All other changes are dampened in the long run.

3.3.4 Business Cycle Boom

To understand how the banking industry responds in a boom interpreted as an increase in productivity, we raise A by 50% (from 0.2 to 0.3). We provide the results in Figure 6 and Table A4.

In the short run, lending rises along with a rise in intermediated output (D rises by 65% while Y rises by 145%). Thus, the model generates procyclical lending. Interest margins, short run profits, and equity values are all procyclical (R rises by 65%, π rises by 167%, and E rises by 158%). While variability of output is procyclical, the variability of equity is countercyclical (the coefficient of variation of output rises 159% while the coefficient of variation of equity rises 3%).

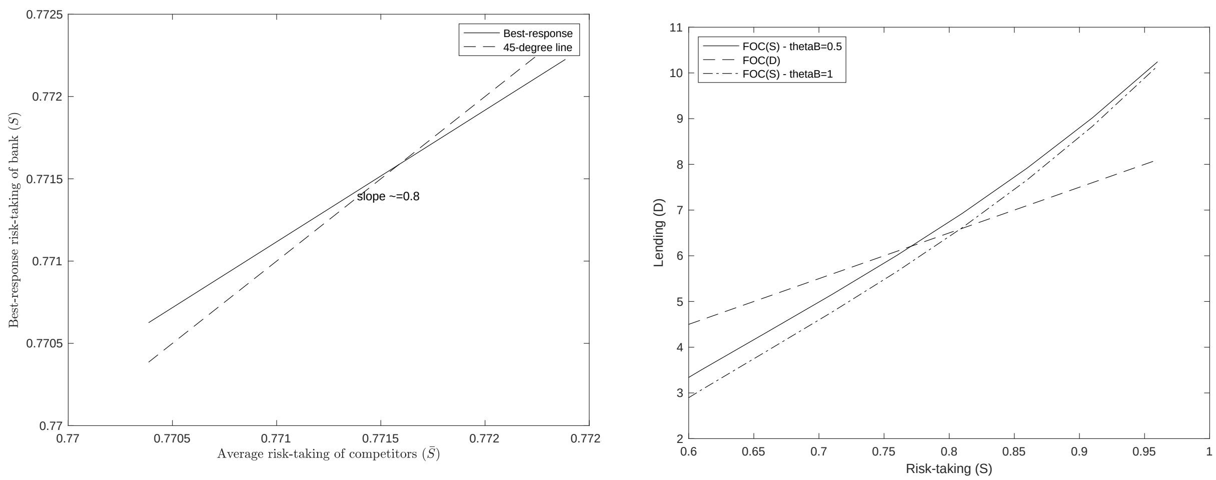
In the long run, entry rises in response to the increase in charter values (N rises 52%) so that we get procyclical entry. The increasing competition induces risk taking in the long run and dampens individual bank lending (S rises 9% and D rises by only 29%). Aggregate lending and output are increased further. While short run leverage was countercyclical (D/E fell 36% in the short run), long run leverage rises (D/E rises 29%).

3.3.5 Contagion

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 [27]), we now consider an alternative technology meant to capture, in a reduced form way, contagion. In particular, we consider an identical environment except for the success probability function. In particular, we take $p(S_i, \overline{S}) = 1 - S_i^\phi \overline{S}^\psi$ where $\phi + \psi = \eta$. That is, bank i's choice of risk depends explicitly on what all other banks' choice of risk ($\overline{S}$) is, similar to how we model the funding technology $r_D(Z)$. 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 [29]. We illustrate the effect by maintaining $\eta = 4$ at our benchmark value, but setting $\phi = 3.5$ and $\psi = 0.5$.

As in Bulow, Geanokoplos, and Klemperer [17], there are *strategic complementarities* if another player's strategy, say $\overline{S}$, increases the optimal strategy of bank i. In figure 7a, 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 in the neighborhood of a symmetric equilibrium.[19] Clearly, as other banks choose more risky strategies, bank i chooses a riskier strategy consistent with strategic complementarity. Another feature of figure 7a is that the best response function has slope less than one.

Figure 7: Contagion



(a) Best Response Function $S(\overline{S})$ with Contagion

(b) Contagion Comparative Statics

In Figure 7b we plot the comparative statics of how risk taking and lending ($D = L$) change as we vary the degree of the externality *theta* in a symmetric equilibrium associated with our benchmark calibration. Since $p(S, \overline{S})$ only affects the first order condition (6) for risk taking and not deposits(7), a higher θ 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 6 and Table A5 for $\psi = 0.5$. In the short run, risk taking and lending rise due to the strategic complementarity (S rises by 4% and D rises by 5%). While interest margins and short run profits rise, equity values fall due to the decrease in success probability (R rises by 5%, π rises by 3%, while p falls by 8% and E falls by 12%). While output rises marginally, the expected cost of deposit insurance rises tremendously (Y rises by 2% and F/Y rises by 43%). The presence of contagion also leads to more variability in output and equity (the coefficient of variation of output rises 31% and the coefficient of variation of equity rises 13%).

[19] 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 $\overline{S}$.

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 (but still higher than the benchmark model without contagion) while individual lending, however, rises even further (S rises 3% relative to the benchmark and D rises by 9%). Despite the rise in aggregate lending, there is no long run change in average output due to the decrease in success probability with contagion. In the long run, expected expenditure on deposit insurance funding rises 28%.

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.

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 [42], Gan [31], Beck, Demirguc-Kunt, and Levine [11], Berger, Klapper, and Turk-Ariss [12], Beck, De Jonghe, and Schepens [12], and Buch, C., C. Koch, and M. Koetter [16] 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. [24], Petersen and Rajan [46], Zarutskie [53], Schaeck, Cihak, and Wolfe [48], Boyd, De Nicolo, and Jalal [15], Houston et. al. [38], Fu, Lin, and Molyneux [30], Akins et. al. [5], and Carlson, Correia, and Luck [18].

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 [39], 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 [40] 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 ([34],[35]) and JLL ([39],[40]). 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 ([34],[35]) 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. [20] 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 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 combing 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

[20] For a more detailed explanation of the construction of competition measures, see JLL ([39],[40], [41]).

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.

Moreover, we find that an intensification of competition increases bank risk. Thus, we confirm the findings in JLL [40] using a regression specification derived from the model presented above. As shown in column (4) of Table 3, a regulatory-induced intensification of the

Table 3: 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

Competition, Charter Value, and Risk

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.

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 [35]) 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 [40] 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. First we derive analytical predictions from the model that can be tested empirically by the signs of our regression coefficients (which depend on the parameterization of the model) in this section. The simulation results in Table A3 under our benchmark parameterization provide consistent testable predictions.

Combining the first-order condition for risk-taking (6) and lending (7) we can obtain the following single equation implicit solution for risk-taking in the short-run:

$$Rp'(S) + p(S)(1 - \beta p(S))A = 0. \tag{24}$$

Totally differentiating (24) with respect to α and simplifying we obtain

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

if $\widetilde{den} = R(\eta-1)+(1-x)[R+\frac{\alpha}{N+1}] > 0$ where $x = (2\beta p(S)-1)(N+1)$. Sufficient conditions for the sign of $\widetilde{den}$ are derived in Appendix C, but in general this condition is guaranteed provided η is sufficiently large. In particular, the sufficient conditions are satisfied for the calibration as well as all the experiments conducted. Thus we predict that in the vicinity of our calibration (and all numerical counter-factuals) $\frac{dS}{d\alpha} > 0$. Hence, in a regression of risk taking on the cost of monetary contraction (among other variables), we should predict the coefficient to be positive. By the same logic, totally differentiating (24) with respect to N we show in the appendix that $sgn(\frac{dS}{dN}) = sgn(\frac{dS}{d\alpha})$.

As we are interested in the differential effects of monetary policy on risk-taking in more or less competitive environments, we now move to signing the cross-partial derivative $\frac{d^2S}{d\alpha dN}$ in (24). By direct computation and simplifying we have

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

If η sufficiently large so that $\frac{dS}{dN} > 0$, then it is sufficient for this cross-partial to be negative if $\frac{dx}{dN} < 0$. The precise condition is derived in the appendix, but is numerically satisfied again for our calibration. Indeed, from our numerical results presented in Table A3, $\frac{d^2S}{d\alpha dN} \approx \frac{dS}{d\alpha}\bigg|_{N=5} - \frac{dS}{d\alpha}\bigg|_{N=3} = 3\% - 6\% < 0$. This cross-partial forms the basis of our prediction that the coefficient of the interaction between monetary contractions and competition should be negative in our risk taking regressions.

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 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.

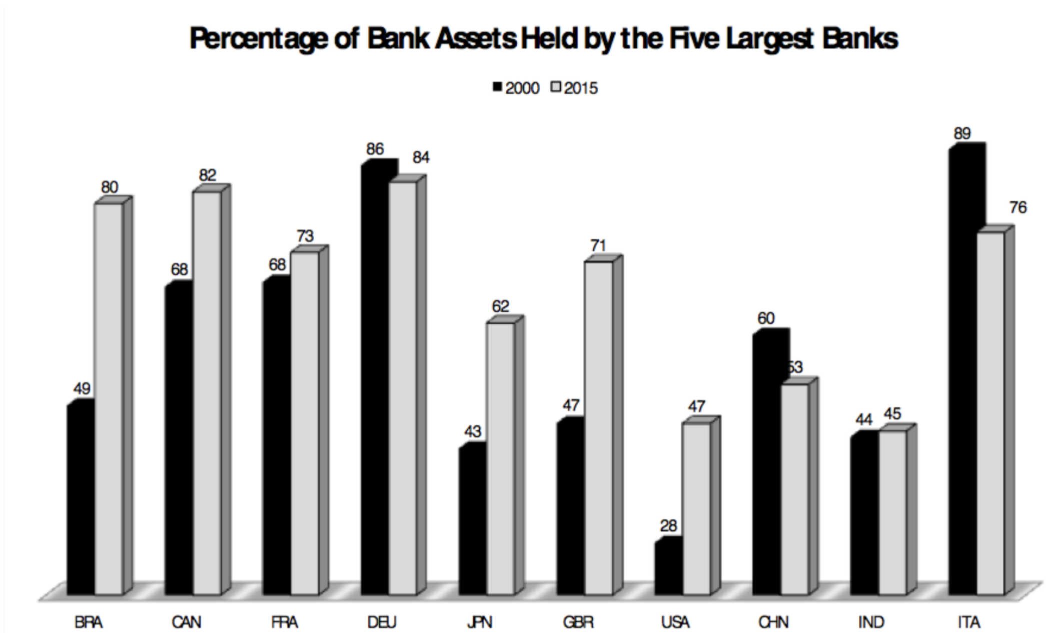
   These findings highlight the enormous welfare benefits of legal and regulatory reforms that improve the incentives of bank decision makers, i.e., that improve bank governance. Such reforms improve bank efficiency, reduce bank fragility, allow for a more competitive banking system without increasing bank 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 8: 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 8 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.

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Appendix

A Planner's Solution

A.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.

A.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.

B Decentralized Solution

B.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

$$F_{SS} \cdot F_{DD} - F_{DS}^2 \quad > \quad 0 \tag{25}$$

Inequality (25) 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 [50]) for a constrained local max reduces to requiring $F_{SS} < 0$.

B.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

$$den = [2A\lambda p'(S)p(S) + p'''(S)p'(S)] < 0 \tag{26}$$

with

$$w'(S) = \frac{-p'(S)}{[1 - \beta p(S)]^2}(\delta - \beta) > 0. \tag{27}$$

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.

B.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.

C 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

$$Rp'(S) + p(S)(1-\beta p(S))A = 0 \tag{28}$$

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 (28) 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:

$$\eta \geq (2\beta p(S)-1)(N+2) \Rightarrow \widetilde{den} > 0. \tag{29}$$

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

$$\frac{dS}{d\alpha} = \frac{S}{(N+1)\widetilde{den}} = \begin{cases} > 0 & \eta \text{ large ie satisfying (29)} \\ < 0 & \eta \text{ small ie satisfying (35)} \\ \text{ambig} & \text{else} \end{cases} \tag{30}$$

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

$$\eta - 1 > \frac{AS(2\beta p(S) - 1)}{(AS-\alpha)}(N+1). \tag{31}$$

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

$$\frac{dD}{d\alpha} = \frac{A\frac{dS}{d\alpha} - 1}{\gamma(N+1)} = \begin{cases} > 0 & \eta \leq 1 \\ < 0 & \eta \text{ large ie satisfying (29) and (31)} \\ \text{ambig} & \text{else} \end{cases} \tag{32}$$

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

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

Re-arranging

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

and simplifying

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

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

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

Again plugging in y and x we have

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

Assuming $1-x<0$ and $\widetilde{den} > 0$,[21] it is sufficient for $\frac{dx}{dN} < 0$ if $\bigg(..\bigg) < 0$.

[21]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

$$\frac{1}{4\beta}<p(S)<\frac{1+2\beta}{4\beta},\widetilde{den}>0 \quad \Rightarrow \quad \frac{d^2S}{d\alpha dN}<0 \tag{33}$$

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 (29), (31) and (33), 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 $\widetilde{den} > 0$.[22] 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

$$\eta \geq (2\beta p(S) - 1)(N + 2).^{23} \tag{34}$$

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

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

[23]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.

$$\eta \leq \frac{1 + (2\beta p(s) - 1)(N + 2)}{2} \tag{35}$$

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

D Supplementary Model Tables

Table A1: Variation in Market Structure

	Planner	**Less Competitive**	**Benchmark** (levels)	**More Competitive**	**Optimal Entry Barriers**
N	NA	1	3	5	2.1
S	-9%	-27%	0.73	13%	-11%
D	NA	31%	5843.22	-22%	12%
Z	-24%	-56%	17529.65	30%	-23%
D/E	NA	-80%	14.89	181%	-50%
p	13%	30%	0.71	-27%	16%
R	NA	31%	0.03	-22%	12%
π^*	NA	124%	121.08	-56%	46%
κ^*	NA	562%	392.47	-72%	124%
V	NA	474%	371.14	-71%	115%
F/Y	NA	-135%	0.18	225%	-79%
Y^*	-22%	-59%	1825.91	8%	-21%
cv(Y)	-52%	-91%	748.57	144%	-58%
cv(E)	NA	-54%	0.64	50%	-27%

Except for benchmark, all columns are percent deviations from benchmark.

* denotes in millions. $Y = p(S) \cdot A \cdot S \cdot Z$.

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

	Eliminating agency SR	**Eliminating agency LR**	**Tightening Leverage SR**	**Tightening leverage LR**
N	3.0	3.1	3.0	5.6
S	-2%	-2%	-19%	-18%
D	-3%	-4%	-47%	-66%
Z	-3%	-1%	-47%	-37%
D/E	-8%	-4%	-66%	-66%
p	3%	3%	23%	23%
R	-3%	-4%	47%	19%
π^*	-2%	-6%	-4%	-51%
E^*	6%	0%	58%	0%
V	11%	6%	58%	-8%
F/Y	-17%	-12%	-115%	-108%
Y^*	-1%	0%	-47%	-37%
cv(Y)	-12%	-9%	-81%	-77%
cv(E)	-6%	-4%	-40%	-40%

Percent deviations from benchmark. * In millions. $Y = p(S) \cdot A \cdot S \cdot Z$. Note here the entry cost κ is held fixed and so in the short-run equity $E^* \neq \kappa$.

Table A3: Monetary Transmission Mechanism Across Market Structures

	Benchmark (levels)	**Contractionary Monetary Policy Benchmark** (N=3)	**Contractionary Monetary Policy Benchmark LR**	**Competitive Benchmark (levels)** (N = 5)	**Contractionary Monetary Policy More Competitive** (N=5)	**Contractionary Monetary Policy More Competitive LR**
N	3.00	0%	-23%	5.00	0%	-18%
S	0.73	6%	0%	0.83	3%	0%
D	5843.22	-9%	0%	4552.91	-11%	0%
Z	17529.65	-9%	-23%	22764.55	-11%	-18%
D/E	14.89	57%	0%	41.86	44%	0%
p	0.71	-12%	0%	0.52	-12%	0%
R	0.03	-9%	0%	0.02	-11%	0%
π^*	121.08	-27%	0%	53.76	-30%	0%
E^*	392.47	-42%	0%	108.75	-38%	0%
V	371.14	-41%	0%	105.97	-38%	0%
F/Y	0.18	35%	-32%	0.57	14%	-19%
Y^*	1825.91	-14%	-23%	1966.93	-19%	-18%
cv(Y)	748.57	24%	-23%	1825.36	5%	-18%
cv(E)	0.64	20%	0%	0.96	14%	0%

Percent deviations of monetary policy contraction from $\alpha = 0.03$ to $\alpha = 0.05$ holding market size fixed at $N = 3$ and $N = 5$ levels respectively.

Table A4: Robustness Part I

	Shadow Banking SR (γ)	**Shadow Banking LR** (γ)	**Regulatory Arbitrage SR** ($\lambda + \gamma$)	**Regulatory Arbitrage LR** ($\lambda + \gamma$)	**Fintech SR** (η)	**Fintech LR** (η)	**Non-Interest Income LR** (ε)
N	0%	-16%	0%	25%	0%	104%	0%
S	-3%	-5%	-18%	-18%	6%	11%	-1%
D	-36%	-29%	-61%	-66%	8%	-36%	-1%
Z	-36%	-41%	-61%	-58%	8%	31%	-1%
D/E	-11%	-29%	-66%	-66%	-75%	-36%	-8%
p	4%	8%	23%	23%	29%	22%	2%
R	-4%	6%	34%	19%	8%	-36%	-1%
π^*	-35%	-18%	-37%	-51%	51%	-50%	3%
E^*	-28%	0%	15%	0%	332%	0%	7%
V	-23%	-2%	15%	-8%	163%	-7%	7%
F/Y	-22%	-45%	-112%	-108%	-105%	-73%	-9%
Y^*	-35%	-39%	-61%	-58%	48%	78%	-1%
cv(Y)	-44%	-55%	-86%	-85%	-67%	-33%	-7%
cv(E)	-8%	-14%	-40%	-40%	-53%	-39%	-3%

In the first two experiments, γ and A are both increased by 50% respectively. The Fintech experiment corresponds to η being increased from 4 to 10,

Table A5: Robustness Part II

	Business Cycle SR (A)	**Business Cycle LR** (A)	**Too Big To Fail SR** ($b = 1$)	**Too Big To Fail LR** ($b = 1$)	**Contagion SR** ($\psi = 0.5$)	**Contagion LR** ($\psi = 0.5$)
N	0%	52%	0%	52%	0%	-6%
S	1%	9%	9%	14%	4%	3%
D	65%	29%	11%	-15%	5%	9%
Z	65%	97%	11%	29%	5%	2%
D/E	-36%	29%	-53%	-15%	20%	9%
p	-2%	-17%	-16%	-28%	-8%	-6%
R	65%	29%	11%	-15%	5%	9%
π^*	167%	39%	3%	-48%	3%	13%
E^*	158%	0%	134%	0%	-12%	0%
V	133%	2%	71%	-7%	-10%	1%
F/Y	33%	162%	100%	234%	43%	28%
Y^*	145%	167%	1%	5%	2%	0%
cv(Y)	159%	358%	68%	148%	31%	20%
cv(E)	3%	31%	29%	54%	13%	10%

The TBTF experiment moves bailout probability from 0 to $b = .8$ with $\theta = .72$. The contagion experiment moves the externality of other banks risk-taking on a given individual banks success probability from $\psi = 0$ to $\psi = .5$.

E Summary of Solution Methods

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

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

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

E.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^*

E.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.

E.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

E.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.