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Macroprudential capital requirements with non-bank finance

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Abstract

I analyze the impact of raising capital requirements on the quantity, composition, and riskiness of aggregate investment in a model in which firms borrow from both bank and non-bank lenders. The bank funds loans with insured deposits and costly equity, monitors borrowers, and must maintain a minimum capital to asset ratio. Non-banks have deep pockets and competitively price loans. A tight capital requirement on the bank reduces risk-shifting and decreases bank leverage, reducing the risk of costly bank failure. In response, though, the bank can change both price and non-price contract terms. This may induce firms to substitute out of bank finance, leading to a theoretically ambiguous effect on the profile of aggregate investment. Quantitatively, I find that the bank's incentive to insure itself against issuing costly equity and competition from the non-bank sector mutes the long run impact of raising capital requirements. Increasing the capital requirement from 8% to 26% eliminates bank failures with effectively no change in the quantity or riskiness of aggregate investment.

JEL codes: G2, E5, E6, E32, E44

Keywords: banking, capital requirements, business cycles

Non-Technical Summary

The financial crisis of 2007-2009 has spurred policymakers to consider many regulations designed to improve financial stability. This paper examines one of the most frequently and aggressively pursued of these proposals: raising bank capital requirements. Capital requirements constrain banks' risk-weighted leverage, which forces banks to internalize risks and maintain larger capital buffers. The riskiness of the banking sector may decline as a result, but so too might bank credit supply if debt financing cannot be replaced by equity one-for-one. Balancing this tradeoff is of first order importance for regulators.

To analyze this tradeoff, this paper studies the effects of changing capital requirements on investment, output, and default when lending can occur outside the traditional banking sector, as in the modern financial system. This "non-bank" sector, comprised mostly of corporate bonds, has grown drastically over the last half century for many major global economies. In the U.S., for example, non-bank debt makes up over 85% of firms' total debt, up from 68% pre-1980. This suggests that inclusion of non-bank financing is critical in constructing a realistic description of the economy's aggregate credit supply.

The effects of changing capital requirements are explored in the context of a novel dynamic, stochastic, general equilibrium model in which firms borrow from both bank and non-bank lenders. Banks are financed with insured deposits, can monitor borrowers to mitigate default risk, and are subject to a capital requirement, while non-banks are not. In the model, tighter capital requirements weaken banks' incentives to "risk-shift;" that is, to benefit from the implicit subsidy of limited liability coupled with insured deposits. Consequently, banks reduce leverage, lowering their risk of failure. At the same time, though, the tighter capital requirements induce banks to raise the interest rates they charge on loans, and in equilibrium firms substitute into non-bank finance.

The quantitative analysis in this paper addresses the question: how does substitution out of bank lending induced by capital requirements jointly impact aggregate default and investment? To evaluate the model's performance, the link between firms' and banks' financing composition and investment is investigated in both the model and the data. This exercise is crucial, given how changes in capital requirements propagate through the economy. Specifically, capital requirements alter banks' financing decisions. These in turn change banks' lending policies, inducing an equilibrium shift in the composition and amount of firms' external financing. As this external financing shifts, so too does firms' investment. In the model, as in the data, (i) firms' investment growth is driven most strongly by non-bank debt, (ii) banks' loan supply is driven mostly by deposits (and other debt), and (iii) there is substantial, though imperfect, substitutability between types of financing.

Since the model matches key targeted moments of the data and performs realistically with respect to untargeted moments, it is then used to consider two forms of policy counterfactuals. In the first, equilibria are compared over a range of capital requirements to determine the long run impacts of the regulatory change. Significantly tightening capital requirements induces large changes in banks' financing behavior, but these changes do not translate into large aggregate effects. Specifically, banks cut their leverage, reducing their likelihood of failure and eliminating it completely at a capital requirement of 26%. At the same time, though, bank loan rates increase only modestly. Therefore, borrowers change neither their leverage nor the composition of their external financing very much, leading to small aggregate effects on output and investment. As a result, even an increase in the capital requirement of 18 percentage points results in a drop in no drop aggregate investment.

What underlies this result? While bank policies are highly sensitive to the level of the capital requirement for low levels of bank capital, they are far less sensitive at high levels. In equilibrium, banks respond to the tighter capital requirement by holding more capital, thereby dampening the impact of the tighter constraint. Moreover, firms' loan demand elasticities are sufficiently high that the bank cannot respond to the tighter capital requirement by raising rates and increasing margins by cutting loan volume. Therefore, the changes in bank lending are small and lead to correspondingly small changes in firms' financing composition, leaving aggregate investment remarkably close to the baseline level in terms of quantity, composition, and riskiness.

The second counterfactual focuses on short run effects to complement the long run effects of the first. Specifically, it considers the transition path of the economy from the current capital requirement regime to a capital requirement of 26%, the level at which bank failures are eliminated in the long run in the model. The same principles still hold. Banks respond by accruing capital through retained earnings, and although bank financing changes, the equilibrium effect on aggregates is small, even along the transition path.

1 Introduction

Excessive risk taking in the financial sector played a major role in the financial crisis of 2008.[1] The pronounced downturn and sluggish recovery following the crisis have spurred policymakers to consider regulations designed to improve financial stability. In this paper, I examine one of the most frequently and aggressively pursued of these proposals: raising bank capital requirements.

By imposing a lower bound on banks' capital to risk-weighted assets ratio, capital requirements restrict the extent to which banks can finance lending with borrowed funds. This in turn forces banks to increasingly internalize the risks in their loan portfolios and build up capital buffers against adverse shocks. While higher capital requirements may decrease risk in the banking sector, they may also induce banks to decrease credit supply. Balancing increased safety with decreased bank credit is one of the key challenges regulators face when setting bank capital requirements from a macroprudential perspective.

This paper studies the effects of capital requirements when lending can occur outside the traditional banking sector, as in the modern U.S. financial system. This "non-bank" sector has grown drastically over the last half century, both in absolute terms and relative to the traditional banking sector, as shown in Figure 1. The size of this sector, comprised of corporate bonds (about 60%), commercial paper (about 2%), and loans from financial institutions other than commercial banks (about 15%), suggests that it must be included to construct a realistic description of the economy's aggregate credit supply. Critically, this sector is not subject to the same regulatory regime as the traditional sector. If capital regulations constrain lending by traditional banks, this non-bank sector can step in and fill the gap, at least partially.[2]

This paper quantitatively analyzes how the substitution from traditional to non-bank lending alters the transmission of a change in capital requirement to aggregate investment. I show that tighter capital requirements make banks safer by promoting larger capital buffers. On the margin, they also induce increases in bank loan rates and therefore promote substitution into non-bank finance, but this effect is quantitatively small. Instead, this substitution keeps the economy's level of output and investment close to levels observed at a lower capital requirement with minimal changes to risk, as measured by either volatility or aggregate defaults by firms. Therefore, even in the presence of spillovers into other financial sectors,

[1] See, for example, Acharya et al. (2013); Gorton and Metrick (2012); Martinez-Miera and Repullo (2017b), among many others.

[2] For example, in a detailed study of firms' financing choices in the wake of the financial crisis, Adrian et al. (2012) find evidence that a shock to the supply of bank credit induces a corresponding increase in firms' demand for non-bank credit. Even though total issuance of credit by the firms in their sample drops, new bank loan issuances decrease by 75% while new bond issuances increase by 50%.

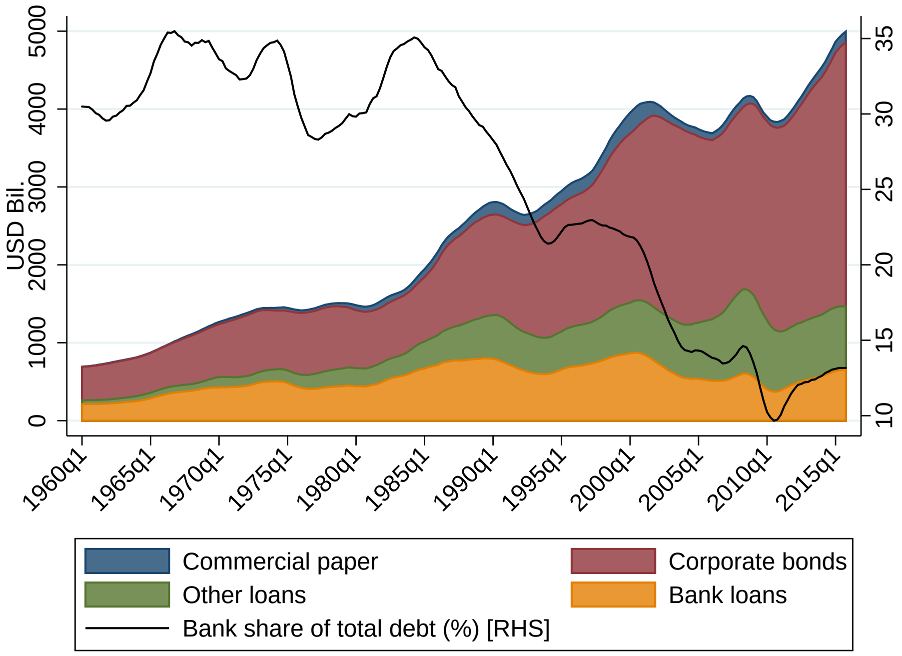

Figure 1: **Growth of alternative debt sources for non-financial business in the U.S.**

Notes*:* Figure is constructed using quarterly data from the Flow of Funds of the Financial Accounts of the United States, 1960Q1 through 2015Q4. Each shaded region represents the total volume of the specified type of debt for non-financial corporate firms. Bank loans are defined as loans from traditional depository institutions, while other loans are comprised of loans from non-bank financial firms.

raising capital requirements to improve bank safety is beneficial.

I obtain these results by developing a novel dynamic, stochastic, general equilibrium model in which firms borrow either from a monopolistically competitive bank or from non-bank lenders. Firms are subject to an agency friction (managerial moral hazard) which yields under-investment, regardless of the choice of lender. I show that the severity of this under-investment may be measured by a single elasticity which varies with the two terms of the lending contract: price and monitoring intensity. Firms choose lenders by comparing the expected returns under each of the two contracts – bank and non-bank – offered in equilibrium. This return has two components: a return conditional on success, and an endogenously determined probability of success. The former depends only on price, while the latter depends on both price and monitoring.

Two main features distinguish the bank from non-banks and motivate capital requirements in the model. First, the bank can alleviate firms' moral hazard by monitoring at a cost, increasing the likelihood of success, which is socially valuable. In contrast, non-banks cannot monitor. Because the bank contract specifies both a loan price and a monitoring intensity, it has two margins by which to impact the quantity and riskiness of the loans it makes. Second, the bank is subject to a moral hazard friction of its own. Given limited liability and deposit insurance, the bank is protected from the downside of its risky loans. Since the bank is protected from loan losses, though, it does not internalize the social benefit of its monitoring. Furthermore, bank failures impose an externality on taxpayers in the form of the costs of insuring deposits. Capital requirements align bank incentives, but also induce the bank to raise loan rates, which causes some borrowers to substitute to non-banks.

The riskiness of firms' investments and the frequency of bank failures in the economy are endogenous functions of the composition of total lending across the safer, monitored bank sector and the riskier, unmonitored non-bank sector. As this composition changes with the capital requirement, so too do aggregate chargeoff rates and volatility. There are two competing effects. First, as the capital requirement increases, banks maintain a stronger capital buffer and are less prone to failure, which is welfare-improving. This benefit, however, must be weighed against a general equilibrium substitution effect. The share of non-bank lending increases to meet loan demand no longer serviced by the banking sector. Since non-bank lenders do not resolve the firm-side moral hazard problem and offer a different loan contract than the bank, and the net impact on the level and riskiness of both output and investment is in general ambiguous.

I turn to a quantitative analysis of the model to resolve this theoretical ambiguity. In Section 4 I calibrate the model to match key aggregates about lending and risk across bank and non-bank sectors in the U.S. Before conducting policy experiments, I compare the link between firms' and banks' financing composition and investment in the model and in the data in order to evaluate the model's performance. This exercise is crucial, since the key transmission mechanism in the model involves cross-balance sheet effects: capital requirements alter bank financing decisions, which change bank lending policies, inducing an equilibrium shift in the composition and amount of firms' external financing, which drives shifts in investment. In my model, as in the data, I find that (i) firms' investment growth is driven most strongly by non-bank debt, (ii) banks' loan supply is driven mostly by deposits (and other debt), and (iii) there is substantial, though imperfect, substitutability between types of financing.

I present the key quantitative properties of the model in Section 5. I show that, while the under-investment induced by the agency friction at the firm level is large, it does not vary widely across lenders. This results stems from the low estimated degree of moral hazard in the model, which is supported in the data by the small difference in risk-adjusted spreads between bank and non-bank loans. This fact, combined with the high elasticity of demand and therefore low degree of effective market power of the bank implies that contract terms and investment outcomes are similar across lenders. I show further that the bank has a strong incentive to maintain a sufficiently large capital buffer that its lending decisions are not distorted by the costs of equity issuance.

I then analyze how key aggregates evolve as the capital requirement is increased in Section 6. This counterfactual experiment suggests that raising the capital requirement beyond its current level would be beneficial. As capital requirements are raised, bank leverage decreases sharply. The rate of bank failure drops, and at a capital requirement of 26%, banks never fail in equilibrium. While the stricter regulation induces sharp effects on bank financing and failure rates, I find that the transmission of these changes to the rest of the economy is surprisingly weak. The explanation for this finding is as follows. As the bank delevers, loan rates increase only modestly, yielding only a modest drop in loan supply and the share of total lending supplied by the bank. In addition, since the estimated benefits of monitoring are small even under the baseline capital requirement, tightening it does little to change default along this margin. As a result, the default rate on and size of bank loans is effectively unchanged. This effect is further muted in equilibrium by the substitution of firms into non-bank finance, and ultimately aggregate investment and output losses in the bank sector are completely offset.

I then investigate the mechanism underlying this sharp dichotomy between the large changes in bank financing behavior and the comparatively small changes in bank lending and macroeconomic aggregates. I show that while the lending policies of a bank with low net worth are very sensitive to the level of the capital requirement, in the long run the bank responds by increasing its capital, weakening the link between its lending policies and deposit financing. This delivers small changes in policies along the equilibrium path. Consistent with the arguments of Admati et al. (2011), retained earnings take primacy and make the adjustment to stricter regulations relatively painless. I argue that it would take an implausibly large degree of moral hazard or a large share (in terms of aggregate investment) of completely bank-dependent firms to reverse this result.

Even though the results of Section 6 show that the costs of raising capital requirements in the long run are quite low, it may be the case that the actual adjustment process is painful. In Section 6.2 I consider a phase-in of the increase from an 8% capital requirement to a 26% capital requirement over 20 quarters in order to address this concern. While the short term effects have interesting dynamics which depend on the way in which the new regime is introduced, the main ideas from the long run analysis still hold.

Ultimately, the quantitative evaluation in this paper offers support for the proposed increase in bank capital requirements, predicting that the reduced risk associated with the policy comes with macroeconomic costs that are quite small, even in the presence of (i) steep costs of equity issuance, (ii) limited substitution out of bank financing, and (iii) a comparative advantage by banks in monitoring borrowers. These results stem from two key effects. First, the dynamic, forward-looking nature of the bank's problem, together with competition from the non-bank sector, makes bank lending decisions, and therefore aggregate investment, only moderately sensitive to the capital requirement. Second, given that the changes in bank behavior are marginal, firms on the margin between bank and non-bank finance can substitute away, and firms not on the margin see little impact.

1.1 Related literature

A growing literature, including prominently Van den Heuvel (2008) and Corbae and D'Erasmo (2014), has attempted to quantitatively assess the effects of capital requirements in general equilibrium models. Recent contributions include Nguyen (2014), whose focus is on growth in the presence of bailouts, and Davydiuk (2017), which solves a Ramsey problem for the optimal capital requirement over the business cycle. In these papers, banks are the only source of external financing for borrowers. Therefore, while the results of these models help assess the effect of regulations on the banking industry, the implied economy-wide impacts do not reflect substitution patterns between lenders.

The analysis of this paper is distinguished by the fact that I explicitly model firms' choice of lender, thereby allowing substitution by borrowers and a richer set of equilibrium responses to changes in capital requirements. The micro-foundations of the model I construct build on Diamond (1984) and Holmstrom and Tirole (1997), in which banks can increase access to credit and total investment by monitoring borrowers to mitigate moral hazard. Several recent papers, including Crouzet (2018) and De Fiore and Uhlig (2011, 2015), apply similar foundations to quantitative models which detail firms' incentives to issue bank and non-bank debt. While well-equipped to study the transmission of lender choice to investment, these models do not analyze lender incentives, and are therefore not suitable for the analysis of bank regulations.

This paper contributes to a newer literature connecting these two strands by modeling not only the decisions of firms, but also the decisions of banks. Regulating the banking sector, then, may cause reactions by banks which induce spillovers into other sectors of the economy, and a macroprudential regulator must account for this. In my framework, the spillovers occur on the asset side of banks' balance sheets: banks can affect the riskiness of the assets in the economy. In independent theoretical work, Martinez-Miera and Repullo (2017a,b) study a framework closely related to the one below in which intermediaries may choose to monitor borrowers, and capital requirements impact the incentives to do so. Relative to their work, I quantify the effect of banks' monitoring choices on aggregate investment, and find that it is small. Perhaps most closely related to my paper is Xiang (2017), which analyzes a quantitative general equilibrium model in which banks offer firms flexibility in financial distress, as in Crouzet (2018). In my framework, lenders can affect the use of the underlying technology, rather than only the liquidation decision of a firm.

Plantin (2015) and Begenau and Landvoigt (2018) offer complementary theoretical and quantitative analyses, respectively, which focus on the liability side of intermediaries' balance sheets: that is, how banks' risk-taking can adversely impact the holders of bank liabilities by limiting valuable liquidity. Begenau and Landvoigt (2018) find an optimal capital requirement in the range of what I find. In these models, asset riskiness is exogenous and banks choose a level of exposure. In contrast, I explicitly model how the composition of debt affects aggregate risk.

2 Model

Time is discrete and infinite. The economy includes three types of agents: firms, banks, and investors (non-banks). There is a single good (capital) used for both consumption and investment. All consumption occurs at the end of the period. There is a riskless asset (storage technology) which delivers a unit of capital at the end of the period for an investment of $\overline{q}$ units at the beginning. There is a single exogenous aggregate state denoted by z_t, described below. I present a detailed discussion of assumptions in Section 3.6, after laying out the full model and its equilibrium.

2.1 Firms

A continuum of identical, risk-neutral firms indexed by j are born at the beginning of each period t with the same initial capital endowment $k_j = \overline{k}_F$. At the beginning of the period, firms borrow, then produce, and finally realize success or failure, repaying creditors and consuming their output net of repayments in the case of success. Then, the period t cohort of firms dies, and a new identical cohort is born at the beginning of period $t+1$.

Firms operate a risky, decreasing returns production technology by investing $I_{j,t}$ units, drawn from internal capital and any borrowing, $b_t(j)$. In the case of success, this investment yields $y_{t+1}(j) = f(I_t(j); z_{t+1})$ units of the good and $\iota b_t(j)$ in the case of failure, where $\iota \in [0,1]$ is a recovery rate parameter. The aggregate shock z_t drives both the productivity of firms and their risk. Higher levels of z_t imply greater output per unit of investment.

Furthermore, projects' riskiness has both an exogenous component and an endogenous one. The exogenous component is π_{t+1}, the probability that a firm succeeds conditional on the manager working. The endogenous component of success probability is determined by firms' responses to an agency friction. To ease exposition, assume that the firm as divided into two parts: a managerial arm and a financial arm. Managers operate the technology of the firm, taking the decisions of the financial arm as given. These financial decisions include the choice of lender $i(j) \in \{B, N\}$ (bank and non-bank, respectively) and amount of borrowing ($b_t(j)$,which pins down the total investment $I_{j,t}$). The choice of lender determines the loan contract $\mathcal{C}_t(j) = (q_t(j), m_t(j))$, where the first term is price of the loan, $q_t(j) = q_{i,t}$ and the second "monitoring intensity" $m_t(j) = m_{i(j),t}$, described below. Given these choices, the manager decides whether to "work" or "shirk" in her operation of the technology. If she works, the probability of success is determined solely by fundamentals, $\pi_{t+1} = \pi(z_{t+1})$. If she shirks, the probability of success is scaled down by a factor of $\kappa \in [0, 1]$. This parameter determines the extent of managerial control over operations; if $\kappa = 0$, managerial shirking has no effect and the agency friction vanishes.

Why would the manager shirk? Each manager's payoff when shirking combines two pieces: the profit of the firm and a non-contractable, private benefit of shirking, which scales with the size of the loan $b_t(j)$. Specifically, each manager realizes an idiosyncratic shock $x_t(j)$ from a distribution $G(x)$. If she chooses to shirk, she obtains benefit $(x_t(j) - m_t(j))b_t(j)$, where $m_t(j)$ is the monitoring intensity of firm j's chosen lender. Managers cannot commit ex ante to working or shirking, and the private benefit is private information and nontradable. These two payoff components receive weights $1-\theta$ and θ, respectively. This parameter governs the severity of the moral hazard friction, together with the managerial control parameter κ. Firms' agency friction vanishes when $\theta = 0$.

The financial arm chooses the source i and size b of the loan taking into account the behavior of the manager. The financial arm maximizes firm value, which does not include the shirking benefit of the managerial arm. Rather, it accounts for the agency friction only insofar as it impacts the probability of success and therefore the total return of the project. When choosing between the two lenders, in addition to the fundamental value implied by the contract of each lender, each firm receives an additive, idiosyncratic preference shock $\nu_t(j) = \{\nu_{i,t}(j)\}_{i\in\{B,N\}}$, which shifts the value associated with borrowing from each lender. This shock is drawn from a type-one extreme value distribution with scale parameter ζ.

2.2 Bank

A single, risk-neutral, monopolistic bank begins the period with net worth K_t and a monitoring technology which can increase managers' cost of shirking. Specifically, at a cost $c(m_{B,t})L_{B,t}$, the bank can lend $L_{B,t}$ to firms and monitor these firms at intensity $m_{B,t}$. This cost function is increasing and convex, and satisfies $c(0) = 1$. In addition to choosing contract terms $\mathcal{C}_{B,t} = (q_{B,t}, m_{B,t})$, the bank chooses how much to borrow from investors at price $q_{D,t}$ in the form of deposits, $D_{B,t}$, and dividends $E_t > 0$ (or equity issuance $E_t < 0$).[3]

Bank deposits are protected by deposit insurance, and the bank itself has limited liability. If the bank's required repayment to depositors exceeds its return on loans, depositors' investment is recouped via a lump-sum, state contingent tax τ_{t+1} on investors next period. The bank is also subject to random capital shocks λ_t which are i.i.d. and occur with probability $\Lambda(\lambda_t)$.[4] These shocks represent an additional source of risk to bank capital above and beyond loan losses, intended to proxy for risk in non-loan investments.

The bank is subject to a capital requirement which specifies that its equity – total assets net of total liabilities – must be at least a fraction $\chi_t \in [0, 1]$ of total lending:

$$q_{B,t}L_{B,t} - q_{D,t}D_{B,t} \geq \chi_t q_{B,t}L_{B,t}, \tag{1}$$

where the left side is the bank's equity (assets minus liabilities) and the right side is total assets, multiplied by the capital requirement χ_t.

Finally, the bank is subject to a financial friction. In the spirit of Gomes (2001) and Jermann and Quadrini (2012), the bank can raise external finance beyond deposits in the form of equity only at a cost. Specifically, the cost of dividends is captured by a valuation function $\xi(\cdot)$ which is strictly increasing for all $E \in \mathbb{R}$, strictly concave for negative E with $\xi'(E) > 1$, and linear ($\xi'(E) = 1$) for positive E. The function ξ captures any direct and agency costs associated with issuing equity.

2.3 Investors (non-banks)

A continuum of identical investors are risk neutral and have deep pockets. Investors are driven to their participation constraints earning, $\overline{r} = 1/\overline{q} - 1$ on all investments. Investors invest in bank deposits, $D_{N,t}$, and direct loans to firms, $L_{N,t}$. Unlike the bank, investors cannot raise the cost of shirking: that is, $m_{N,t} = 0$ for all t, and so $\mathcal{C}_{N,t} = (q_{N,t}, 0)$.[5] Investors take the deposit price $q_{D,t}$ and the non-bank loan price $q_{N,t}$ as given.

[3] It is irrelevant whether the banks set the deposit price or take it as given given the assumptions on investors described below: the equilibrium would remain unchanged under either assumption.

[4] An isomorphic formulation of the model replaces these capital shocks with i.i.d. losses on loans made in the previous period.

[5] This assumption is not critical and can be easily relaxed; all that matters for my argument is that the bank has a comparative advantage in monitoring borrowers.

2.4 Timing

1. At the beginning of the period, the aggregate state of the economy is $s_t = (K_t, z_t)$.
2. Taking optimal firm behavior as given, the bank chooses a loan contract $\mathcal{C}_{B,t} = (q_{B,t}, m_{B,t})$ and a financing mix of deposits $D_{B,t}$ and equity E_t.
3. After receiving their idiosyncratic preference shocks $\nu_t(j)$, and taking contracts $\mathcal{C}_{B,t}$ and $\mathcal{C}_{N,t}$ as given, firms choose their lender $i \in \{B, N\}$ and loan size $b_t(j)$.
4. Investors choose deposits to supply the bank $D_{N,t}$ and loans to supply to firms $L_{N,t}$.
5. Managers realize their idiosyncratic private shirking benefits $x_t(j)$ and choose to work or shirk.
6. The aggregate shock z_{t+1} and individual firms' success or failure are realized. The bank realizes λ_{t+1}, which together with loan returns and deposit repayments implies next period's net worth K_{t+1}.
7. Repayments are made, and consumption occurs. Taxes τ_{t+1}, are levied if necessary.
8. Old firms die and new firms are born.

3 Equilibrium and Analytic Results

In this section, I present the key decision problems and equilibrium conditions of the model. Throughout, I use recursive notation, so a variable x corresponds to x_t, and x' to x_{t+1}. Proofs of all propositions are presented in Appendix A.1

3.1 Firm problem

I analyze the firm problem backwards, beginning with the manager's choice of whether to work or shirk, then the financial arm of the firm's choice of loan size and lender. Firms are ex-ante identical, and are ex post differentiated only by their idiosyncratic shock $x(j)$, loan size $b(j)$, and lender choice $i(j)$. Therefore, I suppress the j index in my analysis.

3.1.1 Manager's problem

From the manager's perspective, the firm's choice of lender only matters insofar as it determines the contract terms $\mathcal{C}_i = (q_i, m_i)$. Therefore, in analyzing the manager's problem, I ignore the choice of lender and take the contract terms and loan size b as the manager's explicit state variables.

Conditional on borrowing b (and therefore investment $I = qb + \overline{k}_F$)[6] and the contract (q, m), a manager must decide to work or shirk having learned her draw of x but not the aggregate z'. Since firms whose manager works succeed with probability $\pi(z')$, and firms who fail receive a payoff of zero, the return from working is simply the expected profits conditional on success[7]

$$\tilde{v}^w(b; q, z) = R(b; q, z) \equiv \mathbb{E}\left[\pi(z')\left(f(qb + \overline{k}_F; z') - b\right)\right]. \tag{2}$$

The return from shirking weighs the profits above against the increased risk of failure and the benefit of shirking, given manager's control κ and the extent of moral hazard θ:

$$\tilde{v}^s(b, x; q, m, z) = (1 - \theta)(1 - \kappa)R(b; q, z) + \theta(x - m)b. \tag{3}$$

The only contract term which affects the value of working (2) is the loan price q. In contrast, both the loan price and the monitoring intensity m affect the value of shirking (3).

Comparing (2) and (3), the manager chooses to work if and only if $\tilde{v}^w \geq \tilde{v}^s$, or

$$x \leq \overline{x}(b; q, m, z) \equiv \left(1 + \kappa\frac{1 - \theta}{\theta}\right)\frac{R(b; q, z)}{b} + m \tag{4}$$

The first term on the right-hand side of (4) represents the expected lost proceeds from shirking, while the second term captures any non-price deterrence of shirking imposed by the lender.[8] Regardless of price, the bank can eliminate shirking by choosing m_B arbitrarily high, though this may be prohibitively costly. The former delivers a leverage effect on project risk, whereby managers at firms with higher leverage stand to gain less from project success per unit of investment relative to shirking, and are therefore more inclined to shirk. Given decreasing returns in the production technology, this first term is also very high for low levels of b, leading moral hazard to increase in loan size, at least initially.

Higher values of both terms increase $\overline{x}$, thereby increasing the likelihood that the firm works. The leverage effect receives relatively more weight if the $1 + \kappa(1 - \theta)/\theta$ term is higher, which occurs when managerial shirking is very costly in terms of output (high κ) or there is

[6]Firms invest all their own capital into the project. Given the risk neutrality of firms, and the presence of the storage technology which caps all prices at $\overline{q} \leq 1$, it is straightforward to show that borrowing will only occur after firms have invested all of their own capital into the productive technology.

[7]Implicit in this formulation is that z shocks are sufficiently small that a successful firm can always pay back its lender. This assumption is trivial to extend, and will be verified in the quantitative analysis.

[8]Slight modifications to the model can capture various other components of relationship lending.

a low degree of moral hazard (low θ). In this latter case, the manager places little weight on the benefits of shirking, and so monitoring plays less of a disciplining role.

3.1.2 Financial arm's problem

The financial arm of the firm makes two decisions each period: the amount to borrow and the source of funds. Each choice is made while accounting for its effect on managerial shirking incentives, and therefore the total level of risk in the project.

Choice of loan size Before the draw of x but after choosing a lender i, a firm must choose how much to borrow, b, in order to maximize expected profits. Since the manager cannot commit to working, the probability of success is endogenous and depends on the loan size b given the contract (q, m). The ex ante probability of a manager working, and therefore succeeding with probability $\pi(z')$, is $G(\overline{x})$, with $\overline{x}$ specified by (4). With complementary probability $1-G(\overline{x})$, the manager shirks, and the firm succeeds with probability $(1-\kappa)\pi(z') < \pi(z')$. The resulting expected probability of working, then, is $G(\overline{x})+(1-\kappa)(1-G(\overline{x}))$, which can be simplified to

$$\psi(\overline{x}) \equiv \kappa G(\overline{x}) + 1 - \kappa, \tag{5}$$

The firm's expected value weighs the expected profits in success against the endogenous probability of success under the agency friction:

$$v(q, m, z) = \max_{b \geq 0} \psi(\overline{x}(b; q, m, z))R(b; q, z) \tag{6}$$

The solution to this problem is summarized in the following proposition. Throughout the paper, I define $\epsilon(x, y)$ to be the elasticity of x with respect to y.

Proposition 1. ***(Optimal loan size)*** *The solution $b^*(q, m; z)$ to problem (6) must satisfy*

$$\epsilon(R, b) = \underbrace{\frac{\kappa g(\overline{x})(\overline{x} - m)}{\kappa g(\overline{x})(\overline{x} - m) + \psi(\overline{x})}}_{=-\epsilon(\psi, b)} \geq 0 \tag{7}$$

where $\epsilon(R, b)$ is the elasticity of return conditional on success with respect to loan size, and the righthand term is the negative of the elasticity of the probability of success with respect to loan size.

Proposition 1 is defines a key mechanism underlying the model. Absent the agency friction, the choice of loan size has no impact on the probability of success, and the elasticity term in equation (7) is equal to zero. The optimal loan size would then set the marginal expected net return equal to zero. The agency friction, then, induces a wedge in the choice of loan size that yields under-investment. The severity of this wedge is determined endogenously by the contract terms offered by bank and non-bank lenders in equilibrium, as well as the distribution of firms' choice of lender.

Choice of lender At the beginning of the period, firms choose a lender i by weighing the relative value under each lender contract implied by the set of contracts available $\mathcal{C} = \{\mathcal{C}_B, \mathcal{C}_N\}$. Given its realized preference shocks ν, a firm solves

$$v_F(\nu; \mathcal{C}, z) = \max_{i \in \{B,N\}} v(\mathcal{C}_i, z) + \nu_i \tag{8}$$

Given the values of $v(\mathcal{C}_i, z)$ from (6), the optimal policy is a threshold rule: $i^* = i$ if and only if $\nu_i - \nu_j \geq v(\mathcal{C}_j, z) - v(\mathcal{C}_i, z)$. Under the assumption that ν_i are i.i.d. type one extreme value with scale parameter ζ, appealing to standard results in the discrete choice literature (see, for example, McFadden (1973); Rust (1987)), the share of firms choosing lender i takes a well-known logit form.

Proposition 2. ***(Equilibrium loan shares)*** *The share of firms choosing bank lending is*

$$\ell(\mathcal{C}, z) = \left[1 + \exp\left\{\frac{v(\mathcal{C}_N, z) - v(\mathcal{C}_B, z)}{\zeta}\right\}\right]^{-1}. \tag{9}$$

Averaging over lender preference shocks, firms' ex ante expected value is

$$w_F(\mathcal{C}, z) = \zeta \ln\left(\exp\left\{\frac{v(\mathcal{C}_B, z)}{\zeta}\right\} + \exp\left\{\frac{v(\mathcal{C}_N, z)}{\zeta}\right\}\right) \tag{10}$$

Finally, the total demand faced for each type of combines the share of firms choosing that loan type given all contracts available and the optimal loan size under that loan type's contract:

$$L_B(\mathcal{C}, z) = \ell(\mathcal{C}, z) b^*(\mathcal{C}_B; z) \tag{11}$$

$$L_N(\mathcal{C}, z) = (1 - \ell(\mathcal{C}, z))\, b^*(\mathcal{C}_N; z) \tag{12}$$

The lender-specific preference shocks induce three properties worth noting. First, ℓ is always strictly positive, so the distribution of lending across lenders is non-degenerate. Second, the share of firms borrowing from the bank increases in the value of the firm under the bank contract; that is, $\partial\ell/\partial v_B > 0$, where v_B is shorthand for $v(\mathcal{C}_B, z)$.[9] As a corollary, firms' modal financing choice delivers the highest value: $\ell > 1/2$ if and only if $v_B > v_N$.

[9] Likewise, for non-banks $\partial(1 - \ell)/\partial v_N > 0$.

Third, lowering the variance of the preference shocks ($\zeta \to 0$) implies that the highest value or modal choice is made by a greater share of firms.

3.1.3 Elasticities of loan demand and loan repayment

The monopolistic bank must consider how firms respond to its loan price and monitoring decisions when it determines the contract, given the aggregate state and the price of non-bank loans. This response has two components: a total loan demand response, and a success probability (or loan repayment) response. As equation (11) shows, the loan demand response may be decomposed into two components: an extensive margin, captured by the loan share ℓ, and an intensive margin, captured by the loan size b. Both contract terms also affect the bank's probability of repayment under the managerial agency friction.

The following proposition provides formal expressions for these responses by exploiting the structure of firms' preference shocks from Proposition 2 and firms' responses to agency frictions in Proposition 1. Specifically, it describes how two of the three key equilibrium objects (loan share and repayment probability) vary with all available contract terms. The elasticity of the loan size is straightforward to compute, but does not lend itself to a closed form calculation like those above. To ease notation, I use the following shorthand: $\ell = \ell(\mathcal{C}, z)$, $v_i = v(\mathcal{C}_i, z)$, $b_i = b^*(\mathcal{C}_i; z)$, $\overline{x}_i = \overline{x}(b^*(\mathcal{C}_i; z); \mathcal{C}_i, z)$, $R_i = R(b_i; \mathcal{C}_i, z)$, and $\psi_i = \psi(\overline{x}_i)$.

Proposition 3. ***(Firm level elasticities)*** *The elasticities of the bank loan share with respect to loan price and monitoring intensity are*

$$\epsilon(\ell, q_B) = (1-\ell)\frac{v_B}{\zeta}\frac{\overline{\epsilon}(R_B, q_B)}{1-\epsilon(R_B, b)} \tag{13}$$

$$\epsilon(\ell, m_B) = (1-\ell)\frac{v_B}{\zeta}\frac{\epsilon(R_B, b)}{1-\epsilon(R_B, b)}\frac{m_B}{\overline{x}_B - m_B} \tag{14}$$

where $\overline{\epsilon}(R_i, q_i)$ is the "direct" elasticity of expected returns in success with respect to loan price, i.e. not factoring in firms' response of b to q.[10] *The elasticity of total bank loan*

[10] The total elasticity of expected returns in success with respect to loan price, $\epsilon(R_i, q_i)$, is

$$\epsilon(R_i, q_i) = \frac{q_i}{R_i}\frac{dR_i}{dq_i} = \frac{q_i}{R_i}\left[\frac{\partial R_i}{\partial q_i} + \frac{dR_i}{db}\frac{\partial b^*}{\partial q}\right] = \overline{\epsilon}(R_i, q_i) + \epsilon(R_i, b)\epsilon(b^*, q_i),$$

where the first term on the righthand side is what I define as the "direct" elasticity. These results are described in more detail analytically in Appendix A.1.3 and quantitatively in Section 5.1.2. Furthermore, the elasticity of the bank loan share with respect to non-bank loan price is

$$\epsilon(\ell, q_N) = -(1-\ell)\frac{v_N}{\zeta}\frac{\overline{\epsilon}(R_N, q_N)}{1-\epsilon(R_N, b)}$$

demand with respect to price and monitoring are the sum of the elasticities of loan size and loan share, i.e. $\epsilon(L,q) = \epsilon(\ell,q) + \epsilon(b,q)$ *and* $\epsilon(L,m) = \epsilon(\ell,m) + \epsilon(b,m)$*. The elasticities of success probability with respect to loan price and monitoring intensity are*

$$\epsilon(\psi, q) = \epsilon(R,b)\left[\frac{\overline{\epsilon}(R,q)}{1-\epsilon(R,b)} - \epsilon(b,q)\right] \tag{15}$$

$$\epsilon(\psi, m) = \epsilon(R,b)\left[\frac{m}{\overline{x}-m}\frac{1}{1-\epsilon(R,b)} - \epsilon(b,m)\right]. \tag{16}$$

Proposition 3 highlights two key properties of the loan demand system and the endogenous level of investment risk. First, each elasticity in (13) through (16) depends directly on the wedge $\epsilon(R,b)$ from Proposition 1. All else equal, the larger is the wedge, the more sensitive are both loan demand and the probability of repayment to contract terms. In the limiting case with no agency frictions, this wedge is equal to zero; this implies that $\epsilon(\ell, m_B) = \epsilon(\psi, q) = \epsilon(\psi, m) = \epsilon(b, m) = 0$, and loan demand is determined exclusively by price on both the intensive and extensive margins. Furthermore, this term completely summarizes the relevant response of loan size to contract terms by embedding the optimal response of the financial arm to the managerial agency friction. As a result, the only other component of the elasticity terms is the direct affect of the given contract term on loan returns or success probability, $\overline{\epsilon}(R,q)$ and $m/(\overline{x}-m)$.

Second, the variance of the lender-specific preference shocks drives the elasticity of demand on the extensive margin. In the limit as $\zeta \to 0$, the loan share is infinitely elastic. Intuitively, as the variance of these shocks decreases, it becomes less likely that a firm receives a shock that results in the contract with higher total value being the one with lower fundamental value. This elasticity effectively determines the bank's market power. Finally, as $\ell \to 1$, loan demand becomes less elastic, since fewer firms remain in the pool to be induced to choose the bank in response to more favorable contract terms.

3.2 Investors

Investors have deep pockets, are risk neutral, and lend to both firms and the bank. To finance both loans and deposits, the following two break-even conditions must be satisfied:

$$q_N^* = \overline{q}\mathbb{E}\left[\iota + (1-\iota)\psi(\overline{x}_N)\pi(z')\right] \tag{17}$$

$$q_D^* = \overline{q}(1+\eta). \tag{18}$$

Equation (17) states that investors must earn the risk-free rate adjusting for firms' default risk. Equation (18) states that investors are indifferent between the risk-free asset and deposits, up to a liquidity premium on deposits, η. At these prices, investors will supply any amount of loans and deposits, yielding the following policy functions:

$$\tilde{L}_N(z) = \begin{cases} 0 & \text{if } q_N(z) > q_N^* \\ [0,\infty) & \text{if } q_N(z) = q_N^* \\ \infty & \text{if } q_N(z) < q_N^* \end{cases} \text{ and } D_N(z) = \begin{cases} 0 & \text{if } q_D(z) > q_D^* \\ [0,\infty) & \text{if } q_D(z) = q_D^* \\ \infty & \text{if } q_D(z) < q_D^* \end{cases} \tag{19}$$

3.3 Bank problem

Given current net worth K and the aggregate state z, the bank chooses a contract $\mathcal{C}_B = (q_B, m_B)$, deposits D_B, and dividends (or equity issuance) E to maximize profits. I explicitly present firms' loan demand from (11) and repayment probability from (5) as functions of the contract terms the bank chooses to underscore the bank's market power. I drop the B subscripts in this section to ease notation. Assembling all constraints, the bank problem is

$$\begin{aligned} V(K;z) &= \max_{q,m,D',E} \xi(E) + \overline{q}\mathbb{E}\left[V(K';z')\right] \\ \text{subject to:} \quad & E + c(m)qL(q,m;z) \leq K + q_D D \\ & q_D D \leq (1-\chi)qL(q,m;z) \\ & K' = \max\left\{0, \left[\iota + (1-\iota)\psi(q,m;z)\pi(z')\right] L(q,m;z) + \lambda' - D\right\} \end{aligned} \tag{20}$$

The objective function incorporates the cost of equity issuance and the discounted continuation value of the bank.[11] The first constraint is the budget constraint, the second is the capital requirement, and the final is the law of motion for bank net worth, where the max operator reflects limited liability. Let $\tilde{L}_B(K,z) = L(q_B^*, m_B^*; z)$ from the problem above denote the bank's loan supply decision.

There are two issues with analyzing problem (20) analytically. First, the capital requirement is in general occasionally binding, and it is difficult a priori to determine when the constraint binds. Second, the max operator in the net worth accumulation equation makes the problem non-convex. Therefore, I leave a full analysis of the bank's problem for the quantitative sections of the paper. To provide intuition, however, I consider a relaxed version of (20) in which the capital requirement always binds and the max operator is removed.[12] In this case, the problem reduces to an optimization in only the contract terms, with deposits

[11] An equivalent formulation defines the bank's state variables as the loans made and deposits issued in the last period, L and D, as well as the capital shock λ. In this case, the last constraint in problem (20) is subsumed in the budget constraint.

[12] In practice, there is little lost in the relaxation of these constraints, since the capital requirement is almost always binding and the bank can issue equity in response to a realization of $K' < 0$.

and equity determined residually. The results of this case are summarized by the following proposition, proven in Appendix A.1.4.

Proposition 4. ***(Bank lending and monitoring policies)*** *In the simplified case of the bank's problem, optimal loan pricing and monitoring policies must jointly satisfy*

$$c(m)\left(1+\epsilon(L,q)\right)-(1-\chi)\left(1-\frac{\overline{q}}{q_D}\mathbb{E}\left[\frac{\xi'(E')}{\xi'(E)}\right]\right)\left(1+\epsilon(L,q)\right) \qquad (21)$$
$$=\frac{\overline{q}}{q_B}\mathbb{E}\left[\frac{\xi'(E')}{\xi'(E)}\left((1-\iota)\pi(z')\psi(q,m)\left(\epsilon(L,q)+\epsilon(\psi,q)\right)+\iota\epsilon(L,q)\right)\right]$$

and

$$c(m)\left(\epsilon(c,m)+\epsilon(L,m)\right)-(1-\chi)\left(1-\frac{\overline{q}}{q_D}\mathbb{E}\left[\frac{\xi'(E')}{\xi'(E)}\right]\right)\epsilon(L,m)$$
$$=\frac{\overline{q}}{q_B}\mathbb{E}\left[\frac{\xi'(E')}{\xi'(E)}\left((1-\iota)\pi(z')\psi(q,m)\left(\epsilon(L,m)+\epsilon(\psi,m)\right)+\iota\epsilon(L,m)\right)\right] \qquad (22)$$

where $\epsilon(c,m)$ is the elasticity of per unit lending cost with respect to monitoring intensity.

Proposition 4 highlights the interactions between firm and bank financing decisions which underpin the model. The top line of each equation is the marginal cost of increasing the relevant contract term, while the bottom line is the associated marginal benefit. The marginal costs, as in standard models of market power, have an elasticity term which reflects the increase in loan demand stemming from the change in the contract term; these terms are analyzed above.

Similarly, the marginal benefit terms reflect that the change in contract terms change the number of units on which the bank will earn the expected loan return, $(1-\iota)\psi(q,m)\pi(z')+\iota$. Given the agency friction in the model, these marginal benefit terms include an additional elasticity term which accounts for the change in repayment probability. This term increases the return on the portion of total lending which may not be recovered in default, but not the purely safe portion.

Equations (21) and (22) also highlight the two key ways in which the financial friction of costly equity issuance and the capital requirement interact and operate in the model. First, given curvature in the $\xi(\cdot)$ function for negative E, the bank has a non-trivial stochastic discount factor, $\overline{q}\xi'(E')/\xi'(E) \neq \overline{q}$. As shown on the righthand side of both equations above, this term affects the evaluation of the increased loan returns from changing price or monitoring intensity on the margin. Shifts in this discount factor may induce changes in contract terms unrelated to firm fundamentals over the business cycle. As a result, shifts in this discount factor are necessary for a change in the capital requirement to result in a change in either the quantity or risk of aggregate investment.

Second, tighter capital requirements directly raise the marginal cost of lending, to the extent that the term

$$\Gamma \equiv 1 - \frac{\overline{q}}{q_D} \mathbb{E}\left[\frac{\xi'(E')}{\xi'(E)}\right]$$

is positive. If the capital requirement binds, it must be the case that the cost of raising a unit in deposits is lower than the expected marginal benefit of saving that unit for the future, which implies that $q_D > \overline{q}\mathbb{E}\left[\xi'(E')/\xi'(E)\right]$, resulting in strictly positive Γ. Therefore, a higher value of χ increases the marginal cost of lending. Alternatively, in the limit as $\chi \to 0$, the bank is able to capitalize more fully on its lending cost advantage by levering up, and raising the capital requirement limits the benefits of this financial strategy.

Ultimately, the bank chooses the pair of contract terms which maximize its value. Crucially, though, this value depends not only on the firm fundamentals in the market, but also on the current financial position of the bank and the future financial position implied by the chosen contract.[13] I explore these interactions further in Section 5.2 below. In the end, though, in order for the capital requirement to impact the terms and quantity of lending, it must induce changes in the bank's discount factor, reflected in a sufficiently large Γ term.

3.4 Fiscal policy

To implement deposit insurance in the case when the bank cannot repay its depositors completely (i.e. the case when limited liability binds), the government levies a tax

$$\tau' = \max\left\{D - \psi(q, m; z))\pi(z'))L(q, m; z) - \lambda', 0\right\}, \tag{23}$$

which is the shortfall of loan repayments relative to the required repayments on deposits.

3.5 Equilibrium definition

A recursive equilibrium in this model is a list of functions

$$\left\{\overline{x}, b_N, b_B, \ell, L_N, L_B, \tilde{L}_N, q_D, \mathcal{C}_N = (q_N, 0), \mathcal{C}_B = (q_B, m_B), \tilde{L}_B, D_B, D_N, E, \tau\right\}$$

in the aggregate state (K, z) that satisfies the following conditions:

1. **(manager optimality)** taking contract terms $\mathcal{C}_i$ as given, $\overline{x}$ is consistent with managerial optimization according to (4);

[13]To see this, in Appendix A.2 I derive equations (A.6) and (A.7), which are the frictionless analogs of equations (21) and (22), respectively.

2. **(loan size optimality)** taking contract terms $\mathcal{C}_i$ as given, firms' choice of loan size b_i solves problem (6);

3. **(lender choice optimality)** taking the set of contracts $\mathcal{C} = (\mathcal{C}_N, \mathcal{C}_B)$ as given, firms choose lender $i \in \{N, B\}$ by solving problem (8), which implies that ℓ satisfies (9) and total loan demands L_B and L_N satisfy (11) and (12);

4. **(investor optimality)** taking firm behavior and prices as given, investors choose loans $\tilde{L}_N$ and deposits D_N according to (19), where q_N^* and q_D^* are given by (17) and (18), respectively;

5. **(bank optimality)** taking firm behavior as given, the bank decision rules $\mathcal{C}_B$, $\tilde{L}_B$, D_B, and E solve problem (20);

6. **(market clearing and consistency)** the following markets clear: (i) deposits, $D_B = D_N$; (ii) non-bank loans, $L_N = \tilde{L}_N$; and (iii) bank loans, $L_B = \tilde{L}_B$.

7. **(fiscal policy)** the tax τ satisfies (23) at the bank's optimal policies.

3.6 Discussion of assumptions

Two-sided moral hazard Capital requirements interact with a two-sided moral hazard friction in the model. The first side is costly managerial effort, which induces a wedge into firms' investment decisions as described by Proposition 1. The bank can lower the effective cost of managerial effort by monitoring. My specification of the moral hazard friction adapts that of Holmstrom and Tirole (1997) with one key modification. I allow investments to still have positive net present value even when the manager shirks, which means that shirking actually occurs in equilibrium. This allows monitoring choices by the bank to influence both the quantity and riskiness of aggregate investment along the equilibrium path, rather than only the quantity.

The other side of moral hazard in the model is a standard risk-shifting friction for the bank. Limited liability and deposit insurance provide the bank a shield against the downside risk of loan losses associated with managerial shirking, which furnishes it with an incentive not to monitor. A tighter capital requirement limits bank leverage and therefore reduces the value of the risk shifting subsidy. This reduces moral hazard for those firms who borrow from the bank to the extent that lower moral hazard for the bank fosters monitoring.

A tighter capital requirement also raises the marginal cost of lending, though, and so the direct effect on monitoring is ambiguous a priori. Furthermore, a tighter capital requirement may induce the bank to cut loan supply, thereby increasing the number of firms borrowing from the unmonitored non-bank sector. Depending on the equilibrium distribution of lender choices, this may increase the total extent of moral hazard even if the bank increases monitoring. The policymaker must trade off these real costs against the benefits of reduced likelihood and costliness of bank failures.

Lender-specific preference shocks The preference shocks in firms' choice of lender (8) tractably create a non-degenerate demand schedule for each type of lending, while maintaining the assumption of ex ante identical firms. Without these shocks, firms would either demand loans from a single lender i or be indifferent between bank and non-bank loans, leading to an indeterminate composition of borrowing across lenders. This feature allows the model to be mapped more easily into the data and smooths out substitution patterns between types of lenders in response to regulatory changes. In the cross-section in the data, no firms completely specialize in direct debt, even though certain classes of firms do specialize completely in bank debt (see, for example, Rauh and Sufi (2010) and Colla et al. (2013)). This model is consistent with there being a set of firms who always choose bank borrowing, but allows the size of this set to be determined endogenously. Furthermore, as discussed above, this structure allows for a single parameter, ζ, which controls the extent of bank market power given the fundamental technologies in the model.

Competition across lender types The bank in the model behaves monopolistically, choosing a lending contract $\mathcal{C}_B$ taking firms' loan demand function as given. A long literature documents that banks have at least some degree of market power, reflected in their profitability and high and stable net interest margins.[14] The extent to which the bank exercises this market power is an important determinant of the share of total debt which comes from bank lending. As will be discussed in more detail in Section 6.2, this has important implications for the bank's ability to capture surplus and therefore retain earnings quickly to meet a higher capital requirement, and so is crucial to the analysis.

Non-banks, in contrast, behave competitively in the model. This is motivated by the low average spreads above fundamental default risk on corporate bonds across risk subgroups, as documented, for example, in Schwert (2018). I choose to keep the modeling of the non-bank sector parsimonious – effectively, just a corporate bond sector – since my focus in this paper is on the disciplining, offsetting role of an outside option for borrowers in the equilibrium assessment of the impact of bank capital requirements on aggregate outcomes.

[14]See, for example, Berger and Hannan (1998); De Guevara et al. (2005).

Firm life span The assumption that firms are short-lived simplifies the analysis of the model by reducing the state space. Long-lived firms would, in general, accumulate capital, and the combination of decreasing returns in production together with idiosyncratic realizations of success or failure would lead to heterogeneity in this capital. In this case, the distribution of firm capital would be a state variable, significantly complicating the analysis.[15] In particular, in this case the bank would have to choose a contract for each type of firm, and so not only the size of the state space, but also the number of control variables in the bank problem would increase.

4 Mapping the Model to the Data

The goal of this paper is to measure the impact of counterfactual changes to capital requirements. Therefore, the quantitative model must be consistent with key empirical facts about firm debt composition, default risk across lender types, bank capital structure, and bank failure risk. I calibrate the model to capture these properties of the data. For the macroprudential policy analysis that follows, the model must deliver reasonable linkages between (i) changes in capital requirements and changes in bank policies, (ii) changes in bank policies and changes in firms' financing, and (iii) changes in firms' financing and changes in investment. In this section, I describe my calibration strategy and assess the model's performance along these dimensions.

4.1 Data sources and sample selection

The model distinguishes firms' capital structure not only between debt and internal financing, but also between bank debt and non-bank debt. Since Compustat does not break down capital structure in this way, I use the Quarterly Financial Report of Manufacturing, Mining and Trade Firms (QFR). I consider only the firms in the data who have access to both bank and bond finance, since all firms in the model have this dual access. Therefore, I follow Crouzet (2018) and focus only on the largest firms, those with assets of at least $250 million in the QFR. The sample period for the QFR is 4Q:1987 through 2Q:2019. Since this is the smallest sample window across all my data sources, I use this window for all the empirical analysis that follows.

All data for the targeted bank moments are taken from the FDIC's Consolidated Reports of Condition and Income ("Call reports") for commercial banks in the United States. Since

[15] An alternative approach would be to treat this potential distribution of firms as a representative "family" of firms, with a single aggregate firm capital state variable which accumulates across periods. Then, much of the existing decision structure could be preserved and the loss intractability would be minor.

all banks lend only to firms in the model, I calculate and target loan volume and chargeoff moments for commercial and industrial (C&I) loans only. Aggregate and business cycle moments are computed using Flow of Funds data. Detailed definitions of moments and descriptions of data sources can be found in Appendix B.

4.2 Calibration

Table 1 presents my calibration of the model. The model period is one quarter.

Parameter		**Value**	**Target**	**Data**	**Model**
Panel A: regulatory and legal framework					
capital requirement	χ	0.08	Basel II baseline	-	-
recovery rate	ι	0.60	Moody's estimates	-	-
Panel B: preferences and agency frictions					
discount factor	$\overline{q}$	0.99	risk-free rate (%)	3.41	3.41
deposit premium (e-4)	η	4.08	liquidity premium (%)	0.17	0.17
pref. shock var. (e-4)	ζ	7.01	bank net interest margin (%)	3.75	3.89
private benefit, mean	μ	4.35	avg. C&I chargeoff rate (%)	0.78	0.60
managerial control	κ	0.10	bank share of debt (%)	23.3	23.4
degree of moral hazard	θ	0.10	relative vol, nonbank debt	1.65	1.42
Panel C: technology					
firm returns to scale	α	0.918	firm leverage (%)	26.3	27.7
bank monitoring cost	$\overline{c}$	0.11	cyclicality, bank share of debt	0.29	0.31
Panel D: aggregate state processes					
productivity, mean (logs)	$\overline{z}$	1.16	autocorrelation, total debt	0.71	0.73
prod., persistence	ρ	0.999	autocorrelation, GDP	0.88	0.76
prod., std. dev. (e-4)	σ	1.01	standard deviation, GDP (%)	1.02	1.02
base prob. of default	$\overline{\pi}$	0.99	corp. bond spread (Aaa, %)	2.80	2.81
cyclical default prob.	δ_π	0.004	cyclicality, corp. bond spread	-0.63	-0.99
capital shock, size	$\overline{\lambda}$	0.015	bank failure rate (%)	0.79	0.80
capital shock, freq. (%)	δ_λ	0.65	bank equity issuance rate (%)	0.07	0.09

Table 1: **Model parameters**

Notes: All interest rates and spreads are reported in annualized net percentage terms. All business cycle moments are computed using the cyclical component of HP-filtered logs of the data, with the standard smoothing parameter of 1600 for quarterly frequency. Firm moments are computed from QFR data, and bank moments are computed from Call Report data. More detail on moment construction is available in Appendix B. Sensitivity of model moments to each parameter is presented in Table C.1 in the Appendix.

Regulatory and legal framework The baseline capital requirement of $\chi = 8\%$ follows the Basel II framework.[16] Recovery rates for bank and non-bank loans (ι) are taken directly from the Moody's report of Emery et al. (2007), with non-bank loans being proxied by senior unsecured corporate bonds. Since my model makes no distinctions based on seniority of debt, I average the recovery rates for bank loans (82%) and senior unsecured corporate bonds (38%), leading to a common recovery rate of 60%.

Preferences and agency frictions The quarterly discount factor, $\overline{q}$, is chosen to be consistent with an annualized risk-free rate of 3.41%, the average of the 1-year Treasury rate over the sample period. The spread η yields a liquidity premium on deposits of 17 basis points, consistent with estimates from the literature (e.g. Begenau and Landvoigt (2018)).[17] The bank values dividends according to

$$\xi(E) = \begin{cases} 1 - \exp(-E) & \text{if } E < 0 \\ E & \text{if } E \geq 0, \end{cases} \tag{24}$$

which is concave for negative E. This specification captures convex costs of equity issuance while still imposing smoothness at the potential kink at $E = 0$ (since $\lim_{E \uparrow 0} \xi'(E) = 1 = \xi'(0)$).

The idiosyncratic preference shocks for firms' choices of lender are drawn from an extreme value distribution with scale parameter ζ. As the variance of this shock increases (higher ζ), firms become less sensitive to contract terms; in the limit as $\zeta \to \infty$, firms exactly split between bank and non-bank lending. For high ζ, then, the monopolist bank has more market power, and so this parameter is pinned down by the bank's net interest margin, which averages 3.75% in the data.

The remaining preference parameters shape the agency friction for the firm. I assume that the private benefit x follows an exponential distribution with mean $\mu = 4.35$, which implies a fat right tail that makes it infeasibly costly to fully eliminate shirking. The managerial control parameter, κ, governs the extent to which managers can affect the success probability of a project. Since the bank can directly affect shirking incentives by monitoring and pricing, this parameter is chosen to match the average share of bank loans to total debt. Finally, the degree of moral hazard θ determines how much total investment fluctuates relative to total productivity in the economy. To avoid the confounding influence of bank monitoring, this

[16] Implicit in this structure is a risk weight on loans of 100%. Since banks in my model hold only one type of asset – C&I loans – and these assets have a risk weight of 100%, this is without loss of generality.

[17] This spread is not necessary for the core insights of the model, but it creates additional persistence in bank leverage in line with the data.

parameter is chosen to replicate the volatility of non-bank debt relative to output, while the mean of the x process is chosen to match the average chargeoff rate on C&I loans for banks.

Technology Firms produce output according to $f(I; z) = zI^{\alpha}$, where z follows the process (25) and $\alpha < 1$ captures decreasing returns to scale. Firms' capital endowment ($\overline{k}_F$) is normalized to 1, and so the returns to scale parameter determines firm leverage, which averages 26.3% in the QFR.[18]

The bank's per unit lending cost function takes the simple quadratic form $c(m) = 1 + \overline{c}m^2/2$, where $\overline{c}$ is the marginal per unit cost of monitoring. When $\overline{c} = 0$, monitoring is costless to the bank, and it would choose to eliminate all shirking by setting $m = \infty$. When $\overline{c} > 0$, monitoring increases the marginal cost of lending, and the bank must trade off risk, return, and cost. The interaction between the bank's willingness to spend on monitoring and the cyclicality in both the financing wedge and the fundamental level of default risk in the economy combine to determine the cyclicality of the bank share of debt, which is 0.29 over my sample period.

Aggregate shock processes The aggregate productivity process is AR(1) in logs:

$$\log z_{t+1} = (1 - \rho) \log \overline{z} + \rho \log z_t + u_{t+1}, \tag{25}$$

where u_{t+1} is a random disturbance distributed normally with mean 0 and standard deviation σ, $\overline{z}$ is the unconditional mean of z, and ρ is a persistence parameter. This process is discretized into a 3-state grid using the method of Adda and Cooper (2003). The high persistence and low standard deviation of this process are chosen to replicate the autocorrelation and volatility of GDP observed in the data. The mean of this process determines the level of investment and firm leverage across all states, and so I determine $\overline{z}$ by matching the persistence of total debt in the economy.

For the state-dependent success probabilities, given the 3-state structure for z, I assume that the baseline success probability in the middle z state is $\overline{\pi}$, which shifts down (up) by δ_{π} in the low (high) z state. The baseline default probability $\overline{\pi}$ parameter determines the fundamental level of firm risk before any monitoring. Thus, this moment pins down the chargeoff rate on non-bank loans. Since these chargeoff rates are difficult to observe directly in my data, and since they map one-to-one to nonbank loan rate spreads in the model, I target the average spread of the annualized Aaa-rated corporate bond rate over the 1-year

[18] The value of $\alpha = 0.92$ is consistent with estimates from the literature, for example Khan and Thomas (2013).

Treasury bill, which averages 2.80% over my sample. Following this intuition, I specify the cyclical variation in π, δ_π, to match the observed cyclicality in corporate bond spreads.

Finally, I assume that bank capital shocks λ have a three point support, $\{-\overline{\lambda}, 0, \overline{\lambda}\}$, with associated probabilities $\{\delta_\lambda, 1-2\delta_\lambda, \delta_\lambda\}$. These parameters jointly determine the failure rate of the bank, 0.79% (in the cross-section) at the quarterly frequency, and bank's propensity to issue equity.

4.3 Validation: financing and investment for firms and banks

The transmission of a change in the level of the capital requirement to aggregate investment has four key links. First, the regulation directly affects bank leverage, altering the liability side of its balance sheet. Second, this change in bank capital structure must induce a change in lending decisions, measured by contract terms. Third, the change in the bank's optimal lending contract induces a change in firms' capital structure on both the intensive (leverage conditional on borrowing from the bank) and extensive (share of firms borrowing from he bank) margins. Finally, this change in firm capital structure must induce a change in firms' investment decisions, either in scale or riskiness.

The goal of this paper, essentially, is to quantify the links in this chain. I explore these effects in Table 2. First, in Panel A, I consider how bank loan growth comoves with bank financing. Since all lending in my model is commercial and industrial lending, I report results for both C&I and total lending in the data. For both measures, in both the model and the data, bank debt growth is most highly correlated bank loan growth, with the strongest effect for deposits.[19] Equity issuance has a much lower correlation, and there is effectively no relationship with retained earnings. These relationships are preserved in the model. Furthermore, in Appendix B, I show that shifts in bank financing appear uncorrelated with changes in the riskiness of bank loans, which is consistent with the findings in the next section

Turning to Panel B, I show how changes in firms' key sources of debt financing vary with investment. Absent detailed micro-level data on the composition of firms' debt and investment decisions, I measure the average correlation between different financing variables and total investment in both the model and the data. To provide additional context, I compare the model to data from both the QFR and the Flow of Funds. Unsurprisingly given the fact that firms in the model do not accumulate capital, the magnitudes of these correlations

[19]Since I have detailed micro-level data for a panel of banks from the Call Reports, I corroborate the findings in Table 2, Panel B in a series of panel regressions in which I can control for bank and time fixed effects. These results are presented in Appendix B in Table B.1. The results of this analysis confirm the findings in the main text.

in the model are larger than in the data. Compared to the QFR, however, the relative magnitudes of the comovements across financing types is preserved. Specifically, changes in investment comoves more strongly with changes in total and non-bank debt, followed by bank debt. Changes in the bank share of debt appear independent of investment. In contrast, in the Flow of Funds, bank debt appears modestly more associated with investment growth. The large comovements of investment with response to key financing variables in the model relative to the data imply that any changes in lending terms associated with capital requirements will tend to be stronger in the model than in the data. Ultimately, my model matches the comovements between measures of financing and investment for both firms and banks observed in the data. The magnitudes of these correlations for bank variables match those in the data, while the analogs for firms are larger.

Panel A: Bank financing and lending

	Correlation of growth in x with loan growth		
Variable, x	**Data (C&I)**	**Data (all)**	**Model**
deposits	0.335	0.556	1.000
non-deposit debt	0.161	0.128	-
total debt	0.511	0.715	1.000
equity capital	0.097	0.167	0.180
retained earnings	-0.050	0.074	-0.047

Panel B: Firm financing and investment

	Correlation of growth in x with investment growth		
Variable, x	**Data (QFR)**	**Data (Flow of Funds)**	**Model**
total debt	0.273	0.113	0.994
bank debt	0.179	0.204	0.921
non-bank debt	0.293	0.025	0.986
bank share of debt	0.041	0.140	0.025

Table 2: **Model vs. data: financing and investment for firms and banks**

Notes: Panel A is constructed from quarterly data from the Call Reports. Each entry is the correlation of the log change in the specified financing variable with the log change in lending. The first column is only C&I lending, while the second is total lending. Panel B is constructed using quarterly data from the QFR and the Flow of Funds, 1987Q4 through 2019Q1 and model analogs. Each table entry is the correlation of the log change in the specified financing variable with the log change in capital expenditures.

5 Quantitative Properties of the Model

This section describes the key quantitative properties of the model. I begin by describing how firm level decisions are affected by the agency friction and respond to contract terms. Then, I consider the consequences of these firm level choices for the key demand and repayment elasticities the bank faces in solving its profit maximization problem. Next, I highlight the role of firms' agency friction and the bank's financial friction in shaping the bank's lending and financing choices. Finally, I summarize the aggregate and business cycle properties of the model.

5.1 Analysis of firm behavior

5.1.1 Loan size and contract terms: the role of the agency friction

The agency friction within the firm shapes both the quantity and riskiness of aggregate investment in the model. In this subsection, I examine how this agency friction shapes firms' investment decisions, taking contract terms as given.

The left panel of Figure 2 shows how the agency friction leads to under-investment, as indicated in Proposition 1. Since the benefit of shirking scales linearly with loan size, but the production function has decreasing returns, the relative value of shirking relative to working grows as loan size increases. Visually, the R elasticity curve is acutely hump-shaped, whereas the ψ elasticity curve has a large flat region which coincides with large b. These forces combine to induce a lower threshold $\overline{x}$ when accounting for the agency friction, which lowers expected returns to the firm by reducing $\psi(\overline{x})$, even though the returns of the project when successful remain unchanged across the two cases.

The right panel of Figure 2 shows how contract terms interact with this agency friction to determine the optimal loan size. For low q (blue and green lines), expected returns to the firm are low relative to the high costs of borrowing, and the optimal scale of investment is low. These low expected returns have two components. First, regardless of monitoring intensity, lower loan prices imply lower net returns conditional on success. Second, given these low returns, shirking is relatively more attractive than working for a fixed loan size, lowering the probability of success. When monitoring intensity is increased, the incentive to shirk is reduced regardless of price, and success probability becomes less sensitive to loan size. As a result, the elasticity curve for $\psi(\overline{x})$ shifts down, leading to an increase in the optimal loan size.

The red lines in Figure 2 show that raising the loan price has a much larger impact on returns than on success probability. This property stems from the endogenous work/shirk

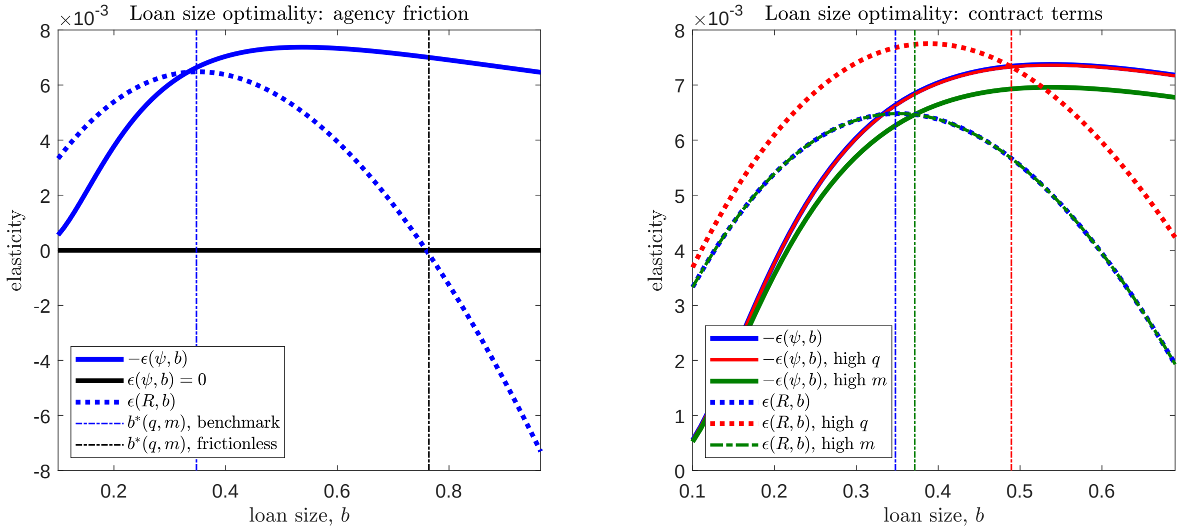

Figure 2: **Loan size optimality**

Notes: Both figures plot the elasticities from equation (7) under the parameters from Table 1 for the average level of z in the economy. The left panel is constructed at the equilibrium level of q_N for this z, with no monitoring. The right panel is constructed at this level of q and m (blue lines), and for two counterfactual levels in which only q is raised (red) and only m is raised (green).

threshold defined in equation (4). As loan size increases, the leverage term $R(b)/b$ in this expression increases more under a high q than under a low q. Given the relatively low estimated degree of moral hazard, θ, this term dominates until b grows large.

Figure 3 summarizes these effects by showing how both the optimal loan size chosen by the firm and the equilibrium level of the financing wedge in equation (7) vary with contract terms. The left panel shows that as q increases, so too does the optimal loan size. The magnitude of this increase, however, varies with the endogenous severity of the agency friction, measured by the financing wedge $\epsilon(R,b)$. In the frictionless case, $\epsilon(R,b) = 0$ always, and so the marginal response of loan size to price reflects only changes in returns conditional on success. In contrast, in the model with agency frictions, the response of loan size to price also reflects the implied change in success probability. Thus while the level of b is higher for a given q in the frictionless case, the responsiveness of b to a change in q is smaller. In the benchmark model, therefore, the optimal loan size is relatively more convex in price, as shown by comparing the solid and dotted lines in the left panel.

By reducing managers' probability of shirking directly and therefore muting the success probability margin of the response described above, monitoring brings firms' loan size choice for a given price closer to the frictionless level. As shown in the left panel of Figure 3, this implies a reduction in the financing wedge. Turning to the right panel, we see the important interaction between monitoring and loan price. At a low q (solid line), increasing monitoring

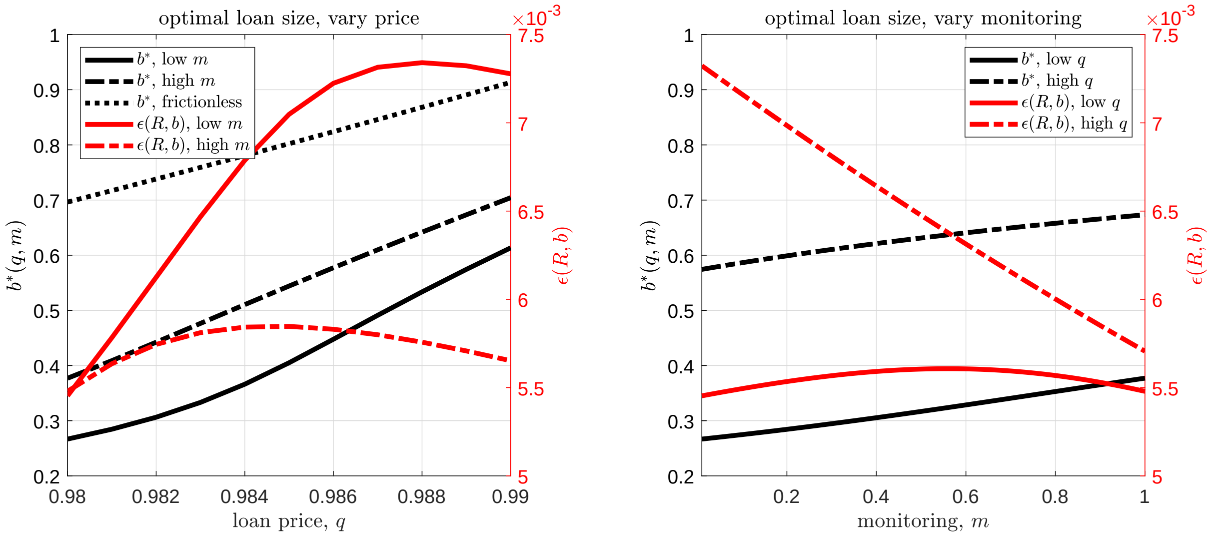

Figure 3: **Loan size and financing wedge by contract terms**

Notes: The optimal loan size maximizes (6) given the contract terms (q, m). Both figures are constructed under the parameters from Table 1 for the average level of z in the economy.

sharply increases loan size by effectively holding the level of the financing wedge constant. In contrast, at a high q, where the optimal loan size and therefore the temptation to shirk and therefore the size of the wedge are larger, increasing monitoring sharply reduces the size of the financing wedge on the margin. In the limiting case with no frictions, the optimal loan size is invariant to monitoring intensity.

5.1.2 Loan demand and repayment elasticities to contract terms

Three components of aggregate investment respond to loan contract terms in the model. The first two, loan size and success probability, are described in the previous section. These terms respond only to the terms of the contract offered by a given lender, $\mathcal{C}_i$ for $i \in \{N, B\}$. The third component, the share of firms choosing bank lending, ℓ, responds to the full set of contracts available in equilibrium, $\mathcal{C} = \{\mathcal{C}_N, \mathcal{C}_B\}$. In Figure 4, I hold fixed the non-bank contract, $\mathcal{C}_N$, at its equilibrium level for a given aggregate state and show how these three components change with respect to the terms of the bank contract, $\mathcal{C}_B$.

The top panels of Figure 4 show how the loan size, loan share, and success probability vary with loan price q for various levels of m. Three properties are worth noting. First, the magnitude of the response to a change in price is largest for loan share, followed by loan size, followed by success probability. This high sensitivity to price comes from the low estimated level of ζ, which implies that the elasticity of the loan demand the bank faces is extremely high on the extensive margin. Firms readily substitute out of bank lending if offered better

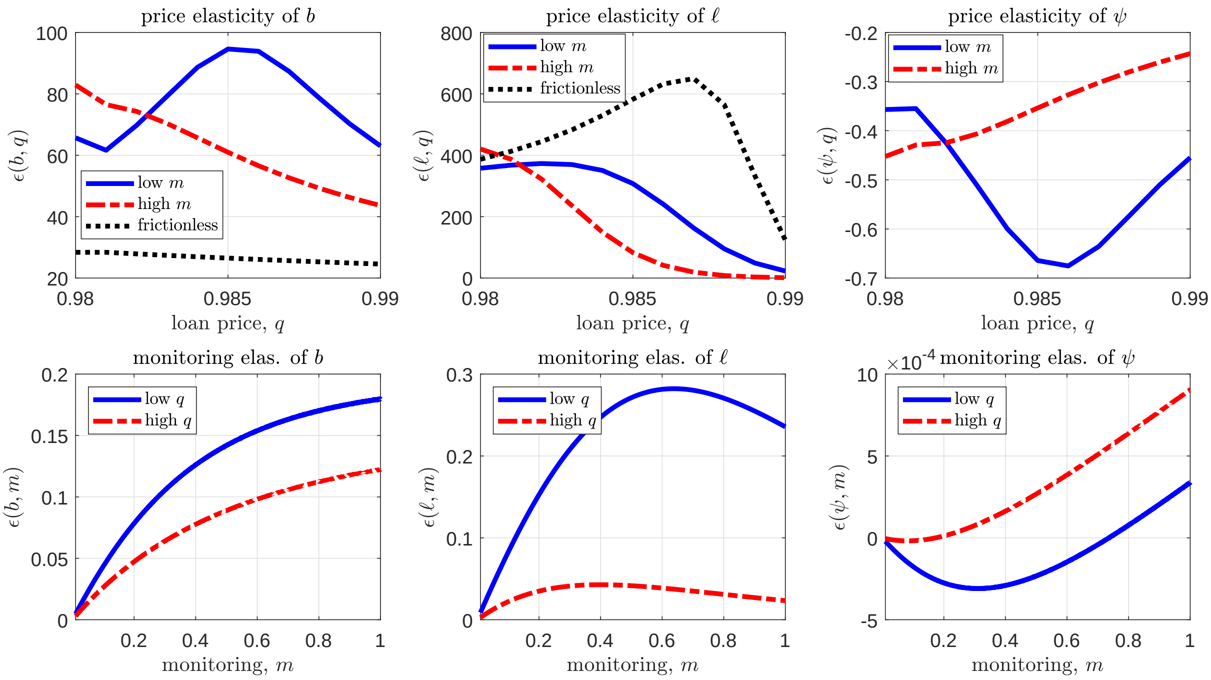

Figure 4: **Key loan demand and repayment elasticities across contract terms**

Notes: The loan size elasticity $\epsilon(b,q)$ and $\epsilon(b,m)$ are computed using numerical differentiation for loan sizes which maximizes (6) given the contract terms (q,m). The loan share ($\epsilon(\ell,q)$ and $\epsilon(\ell,m)$) and repayment probability ($\epsilon(\psi,q)$ and $\epsilon(\psi,m)$) elasticities are computed using equations (13) through (16). All figures are constructed under the parameters from Table 1 for the average level of z in the economy, taking the equilibrium q_N as given.

prices by non-bank lenders, eroding the bank's market power. Second, monitoring has a significant effect on these elasticities. As discussed above, for high enough m, firms behave as in the frictionless case. Increasing monitoring lowers both components of the demand elasticity (b and ℓ) and the repayment elasticity.

Third, the elasticity of loan size (share) with respect to price is much higher (lower) than the frictionless case. The loan size result follows from the analysis of the previous section. Specifically, there are two dimensions of the response of loan size to a change in loan price – returns conditional on success and probability of success – both of which move in the same direction for a fixed b when q is increased. The loan share result also stems from this same dynamic. A lower price implies a smaller loan size and therefore a lower incentive to shirk. While the former effect lowers firm value according to (6), the latter effect raises firm value. Consequently, the value differences between lenders for a given pricing gap is smaller, and equation (9) implies a smaller shift in demand on the extensive margin.

The bottom three panels of Figure 4 show that the elasticities of both loan demand and repayment with respect to monitoring intensity are much smaller than their counterparts with respect to loan price.[20] Increasing monitoring increases demand on both the intensive and extensive margins, with the effect more pronounced for lower loan prices. Interestingly, increasing monitoring in some cases (particularly for low q) can negatively impact success probability because it induces larger loan sizes, increasing the incentive to shirk through the leverage effect.

5.2 Analysis of bank behavior

The bank takes the demand and repayment elasticities in the preceding section as given when choosing its optimal contract terms. In this regard, bank decisions account for the agency friction within firm and determine both its loan supply and the level of risk in its loan portfolio. Moreover, the bank faces a financial friction (costly equity issuance), and this friction interacts with the capital requirement as outlined in Proposition 4. Therefore, the financial position of the bank feeds back into its choice of contract terms, and therefore into the quantity, composition, and riskiness of aggregate investment in the economy. These forces are at the heart of my analysis, and so in this section I analyze the role of each friction in shaping the decisions of the bank.

In order to isolate the role of each of these forces, I consider two variants to the benchmark model. First, I construct a "no agency friction" economy, in which managers are assumed to work all the time, no matter the contract terms.[21] In this case, monitoring plays no role and contracts may be expressed as simple prices, $\mathcal{C}_B = q_B$ and $\mathcal{C}_N = q_N$. Second, I consider a "costless equity" model in which firms face the agency friction as in the benchmark model, but the bank faces no costs of equity issuance. In this variant, equation (24) is replaced by $\xi(E) = E$ for all E. This model variant kills any loss aversion on the part of the bank.

Figure 5 shows how bank policies change over a range of capital levels for each of these model variants, revealing three key insights. First, bank policies only depend on capital when the bank must issue equity today in order to implement its unconstrained optimum. Comparing the benchmark and costless equity models, we see that bank policies across all choices coincide once bank capital is sufficiently high. When capital is low, however, the bank increases the interest rate spread it charges relative to non-bank loans and lowers its monitoring intensity. Both effects increase the riskiness of the bank's loans, making the bank contract less desirable compared to the non-bank contract. Therefore, bank loan demand falls, and the bank lowers its deposit base and issues less new equity relative to the case without costly equity issuance.

[20] As will be documented below, this holds true even if the relevant loan price elasticity terms are expressed in the more commonly used interest rate elasticity terms.

[21] One can construct the economy with no agency frictions by setting $\theta = 0$.

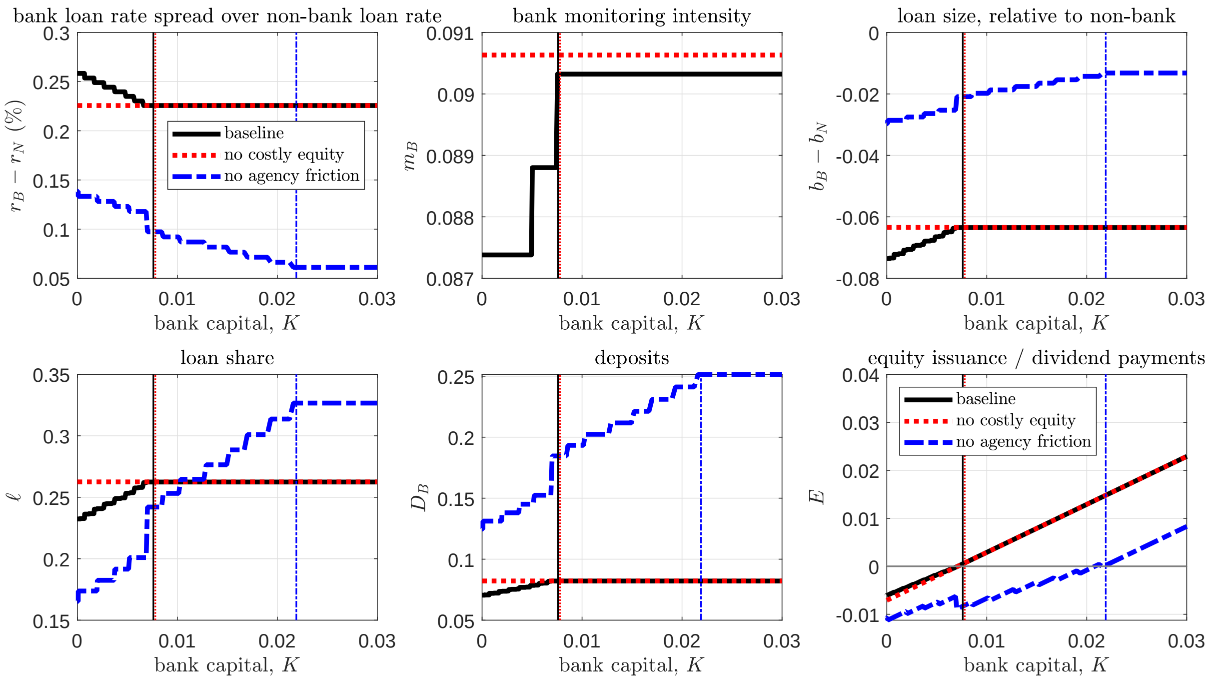

Figure 5: **Bank policies across model variants**

Notes: All figures are constructed under the parameters from Table 1 for the average level of z in the economy, taking the equilibrium q_N as given. In each figure, the vertical line corresponds to the average level of bank capital in the specified model variant.

Second, the agency friction sharply alters the optimal contract offered by the bank and the financing combination the bank chooses to implement it. Absent the agency friction, monitoring serves no purpose, price has no impact on the likelihood of success, and loan demand is determined entirely by prices. The value to the firm from investing a given amount b is sharply higher in this case, and so firms respond more on the margin of lender choice to price. As a result, the bank must offer an interest rate that is much closer to the competitive non-bank rate in order to compete in the market. Demand increases on both the intensive and extensive margins, and the bank takes on a larger share of total lending, which it finances through increased internal capital and deposits.

Third, and most importantly, in both the benchmark and no agency friction models, the bank's average level of capital is the smallest level at which equity issuance is avoided. In this way, the bank the bank maximizes the portion of funding which it draw from low cost deposits while still avoiding the costs of equity issuance. Costly equity, then, tends to limit the bank's exposure to failure, as it optimally avoids these costs by building up a base of capital.

Since the model includes aggregate shocks, a full description of bank behavior must de-

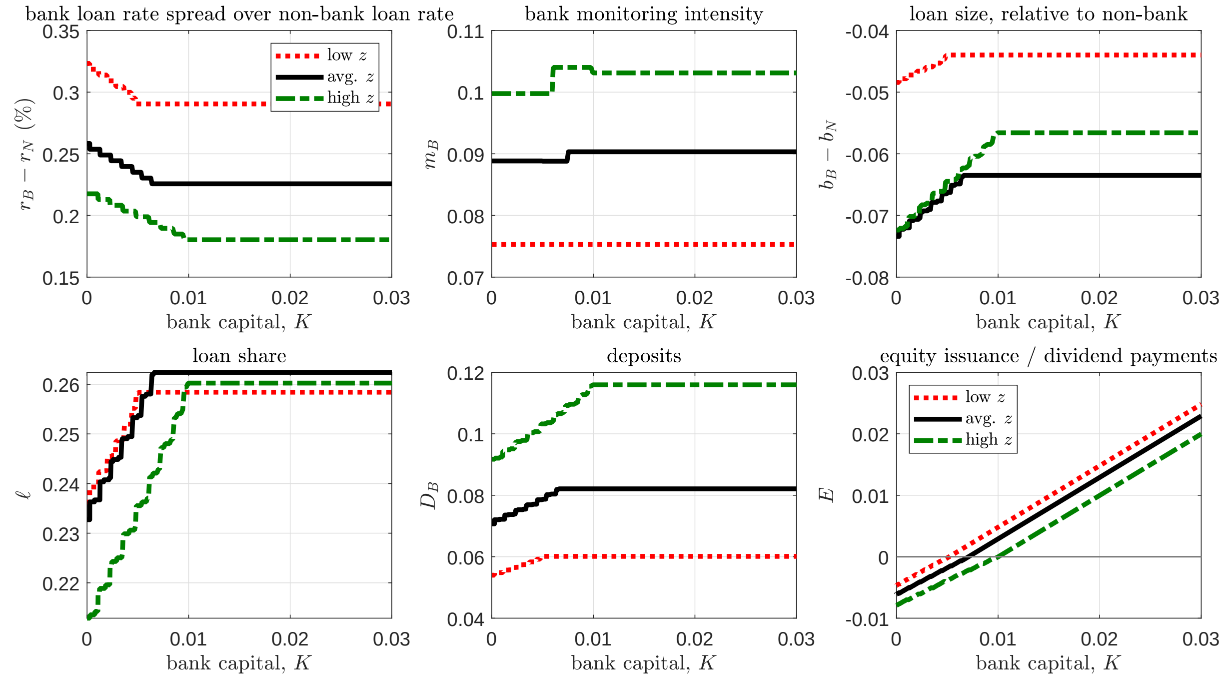

Figure 6: **Bank policies across aggregate states in baseline model**

Notes: All figures are constructed under the parameters from Table 1 across levels of z in the economy, taking the equilibrium q_N as given.

scribe the decisions across states which drive the cyclical properties of the model. To this end, Figure 6 shows how the bank's policies vary across z states in the benchmark model. Turning first to pricing, and recalling from Table 1 that non-bank loan rates are countercyclical, the spread of the bank loan rate over the non-bank rate is also countercyclical; when z is low, the bank chooses a rate 28 basis points (bps) above the non-bank rate, whereas in high z states this figure is only 17 bps. The bank's monitoring intensity is procyclical, contributing to the procyclicality of the overall bank share. In good states of the world, scaling total lending up is desirable, and increasing monitoring is a cost effective way for the bank to do this.

From a financing perspective, in higher productivity states of the world the bank has a larger demand for funds. This increase has the first order effect of expanding the bank's deposit base. On the margin, though, the bank is also more willing to issue new equity. Over time, given the fundamental persistence in the aggregate shock process, this implies that the bank tends to build up its capital base in high z states.

5.3 Aggregate and business cycle implications

In this this subsection, I document how the decisions analyzed in the preceding subsections shape the average and cyclical properties of the economy in the aggregate. Table 3 describes the key financing, investment, and risk moments across the three model variants considered in the preceding section. Panel A describes the bank's financing and lending decisions. The capital requirement almost always binds across all three models, leading to a leverage ratio of 92% with almost no volatility or cyclicality. Bank capital is small on average, approximately 0.76% of the firm endowment size. This level of capital is relatively stable over the cycle, since the fundamental buffering motive against equity issuance costs holds across all z realizations. However, since the bank's optimal lending quantity is procyclical, this motive implies that bank capital is procyclical in the aggregate. The bank is reluctant to issue equity, but does so almost exclusively in bad states of the world. Furthermore, consistent with the data, the bank's net interest margin is relatively stable and nearly acyclical.

Broadly, these properties hold across all three versions of the model. Notably, however, without agency frictions, the bank tends to hold almost three times as much capital, since the optimal quantity of lending is much larger. While the bank's leverage is unchanged, and the chargeoff rate on loans drops by only 20bps, this increased capital buffer effectively eliminates failures due to direct shocks to bank capital. Furthermore, the bank operates on a slimmer profit margin in this case, reflecting the tighter competition with non-bank lenders when success probability is invariant to contract terms.

Panel B of Table 3 aggregates across firms to summarize the average and cyclical properties of aggregate investment and output. Panels C and D disaggregate these results to bank borrowers and non-bank borrowers, respectively. The bank share of debt of 23% implies that firms pay an average interest of just over 3.07%, averaging over the 2.8% from non-banks and 3.9% from banks. As in the data, all these interest rates are strongly countercyclical. Unlike the data, though, these interest rates are relatively stable over the cycle.

Similarly, aggregate chargeoffs sum over the chargeoffs from each lender. Critically, while the chargeoff rate for banks is lower than for non-banks, the size of this difference is only on the order of ten bps. Looking ahead to the effects of capital requirements on changing the riskiness of aggregate investment, this insight is important. Since the estimated degree of moral hazard in the economy is small, the bank tends to compete for market share on price rather than risk abatement. Thus, the endogenous difference in riskiness between bank and non-bank loans is small. The costly equity issuance friction in the model operates mainly through the average level of capital the bank holds in equilibrium. The bank chooses to maintain capital such that its lending decisions are not distorted by low net worth, and aggregate moments barely differ between the benchmark and costless equity models.

Moment, x	Benchmark μ_x	Benchmark $\frac{\sigma_x}{\sigma_y}$	Benchmark ρ_{xy}	Costless Equity μ_x	Costless Equity $\frac{\sigma_x}{\sigma_y}$	Costless Equity ρ_{xy}	No Agency Fric. μ_x	No Agency Fric. $\frac{\sigma_x}{\sigma_y}$	No Agency Fric. ρ_{xy}
Panel A: bank leverage and financing									
bank leverage (%)	92.0	0.00	0.02	92.0	0.00	0.01	92.0	0.00	0.00
average capital (e-2)	0.76	0.14	0.23	0.78	0.14	0.27	2.19	0.25	0.12
bank failure rate (%)	0.72	5.63	-0.01	0.66	5.35	0.00	0.00	0.00	0.00
equity iss. rate (%)	0.08	0.12	-0.96	0.07	0.12	-0.98	0.04	0.21	-0.99
net interest margin (%)	3.89	0.64	0.05	3.88	0.62	0.08	2.27	0.48	0.00
monitoring intensity	0.09	0.28	0.99	0.09	0.28	1.00	0.00	0.00	0.00
Panel B: aggregate outcomes across all firms									
bank share of debt (%)	23.4	0.26	0.29	23.4	0.15	0.98	32.1	1.08	-0.33
total debt	0.39	1.72	1.00	0.39	1.72	1.00	0.84	1.49	1.00
avg. interest rate (%)	3.07	0.08	-0.99	3.07	0.08	-0.99	1.92	0.21	-1.00
firm leverage (%)	27.7	0.96	1.00	27.7	0.96	1.00	45.4	0.56	1.00
chargeoff rate (%)	0.65	0.02	-0.36	0.65	0.02	-0.36	0.43	0.05	-0.78
output	1.55	*1.02*	1.00	1.55	*1.00*	1.00	2.01	*1.00*	1.00
Panel C: outcomes for bank borrowers									
total debt	0.09	0.53	0.97	0.09	0.59	1.00	0.27	0.94	0.40
avg. interest rate (%)	3.81	0.11	-0.96	3.79	0.12	-0.97	2.10	0.21	-0.99
firm leverage (%)	25.6	0.98	1.00	25.6	1.00	1.00	45.2	0.56	1.00
chargeoff rate (%)	0.60	0.02	-0.35	0.59	0.02	-0.34	0.42	0.05	-0.78
output	1.51	0.98	1.00	1.51	1.00	1.00	2.00	1.00	1.00
Panel D: outcomes for non-bank borrowers									
total debt	0.30	1.42	1.00	0.30	1.35	1.00	0.57	1.58	0.91
avg. interest rate (%)	2.81	0.07	-0.99	2.81	0.07	-0.99	1.84	0.21	-1.00
firm leverage (%)	28.5	0.95	0.99	28.5	0.94	0.99	45.6	0.55	1.00
chargeoff rate (%)	0.67	0.02	-0.36	0.67	0.02	-0.36	0.44	0.05	-0.78
output	1.56	1.01	1.00	1.56	1.00	1.00	2.01	1.00	1.00

Table 3: **Moments across model variants**

Notes: All moments are computed by solving the model and simulating it for 10,000 periods, eliminating the first 1,000 to avoid any initial condition bias. Detailed moment definitions can be found in the Appendix. All means (μ_x) are computed from levels, while relative standard deviations (σ_x/σ_y) and cyclical correlations (ρ_{xy}) are computed from log HP-filtered model data with a smoothing parameter of 1600.

Turning to the model with no agency frictions, two results stand out. First, on average, the economy with no agency frictions has the following properties: (i) a higher bank share of total debt; (ii) higher overall leverage and lower interest rates; (iii) higher output; and (iv) lower default risk. These properties hold both in the aggregate and by borrower type. Second, the cyclical properties of this economy closely track the benchmark.

Given the frictions in the model, a useful way to analyze the aggregate results in Table 3 is to analyze the properties of the firm- and bank-level frictions which generate them. This analysis is presented in Table 4 below, which quantifies the equilibrium levels of the key financing variables and elasticities described in Propositions 1, 3, and 4. Since the cyclical behavior of the three economies in Table 3 are broadly similar, in this section I focus only on averages.

Panel A analyzes investment decisions at the firm level, conditional on a choice of lender. Given the equilibrium interest rates in the model, firms who borrow from banks have about 13% smaller average loan sizes. However, the financing wedge, $\epsilon(R, b)$ is also smaller for these firms, and the probability of the manager working is also higher as a result. Critically, though, the magnitude of these latter effects pale in comparison to the loan size effect. Consequently, only 26.2% of firms on average choose to borrow from the bank. These results are unchanged with costless equity issuance because in equilibrium the bank chooses to hold a level of capital which buffers it against the distortion, and so in both models the bank on average makes the unconstrained choice. When the agency friction is removed, managers work all the time regardless of the contract terms, and there is no financing wedge. As a result, firms flow to the lender offering lowest price. The gap in pricing, and therefore loan sizes, between bank and non-bank decreases in this model, but the bank optimally chooses to capture only 32% of the lending market.

Panel B shows how the elasticities from Proposition 3, depicted across contract terms in Figure 4, vary across the three models at the equilibrium contract terms. Given the high share of working firms at each lender from Panel A, the interest rate elasticities of loan demand are much larger than their monitoring intensity counterparts. This implies that price is the main source of competition in lending contracts in the model economy. Furthermore, the extensive margin sensitivity, $\epsilon(\ell, r)$, is much larger than the intensive margin elasticity, $\epsilon(b, r)$, another indication of the bank's low effective market power. In the economy with no agency frictions, monitoring plays no role, and there is no probability of success margin to consider. As a result, firms are much more sensitive to the price offered by each lender. Since interest rates are lower across the board and firms are closer to optimal scale, the intensive margin of loan demand is less active.

Moment, x		Benchmark	Costless Equity	No Agency Fric.
Panel A: firms' loan demand and loan repayment				
non-bank loan size	b_N	0.411	0.411	0.851
non-bank work share	$\psi(\overline{x}_N)$	0.995	0.995	1.000
non-bank wedge (e-2)	$\epsilon(R_N, b_N)$	0.680	0.680	0.000
bank loan size	b_B	0.357	0.357	0.838
bank work share	$\psi(\overline{x}_B)$	0.996	0.996	1.000
bank wedge (e-2)	$\epsilon(R_B, b_B)$	0.621	0.621	0.000
bank share (count)	ℓ	0.262	0.262	0.325
Panel B: demand and repayment elasticities, bank borrowing				
IR elas., loan size	$\epsilon(b_B, r_B)$	-1.308	-1.303	-0.349
IR elas., loan share	$\epsilon(\ell, r_B)$	-6.445	-6.443	-10.54
IR elas., repayment	$\epsilon(\psi, r_B)$	0.008	0.008	0.000
m elas., loan size	$\epsilon(b_B, m)$	0.033	0.032	0.000
m elas., loan share	$\epsilon(\ell, m)$	0.114	0.112	0.000
m elas., repay. (e-4)	$\epsilon(\psi, m)$	-1.144	-1.101	0.000
Panel C: bank monitoring and financing				
monitoring intensity	m	0.089	0.087	0.000
m cost elas. (e-4)	$\epsilon(c, m)$	3.209	3.094	0.000
marginal valuation (e-3)	$\xi'(E) - 1$	0.067	0.000	0.089
Γ factor (e-3)	Γ	0.015	0.014	0.015

Table 4: **Agency and financial frictions over the business cycle**

Notes: All moments are computed by solving the model and simulating it for 10,000 periods, eliminating the first 1,000 to avoid any initial condition bias. Detailed moment definitions can be found in the Appendix. All means (μ_x) are computed from levels. Interest rate elasticities, $\epsilon(\cdot, r)$, can be derived from price elasticities using $\epsilon(\cdot, r) = -(1-q)\epsilon(\cdot, q)$.

Finally, Panel C presents banks monitoring cost and equity valuation terms. Again, even these moments vary little between the benchmark economy and the case with costless equity issuance. At low levels of monitoring, the elasticity of lending cost is quite low, leading to minimal distortion in the bank's choice of monitoring intensity. This result effectively eliminates the prospect of capital requirement changes inducing large changes in bank monitoring behavior. Additionally, even given the sharp curvature in $\xi(E)$, the average marginal value of a dividend in the model is extremely close to 1. This implies that the distortion in the optimal choice of lending terms associated with a change in capital requirements is small.

6 Effects of Increasing Capital Requirements

The key tradeoff for setting capital requirements from a macroprudential policy perspective is increased safety in the banking sector with decreased credit supply and investment. I now present results for each side of this tradeoff. I first consider a steady state analysis in Section 6.1 by solving the model for several levels of the capital requirement, ranging between 1% and 35%. These results can be thought of as long-run comparisons: for each level of the capital requirement, I solve for a new equilibrium. A key effect which emerges is that the aggregate impact of capital requirement changes is small in the long run because the bank adjusts its level of capital in response to the change in regulation. Therefore, to complete my analysis, in Section 6.2 I analyze a series of transition paths between the current capital requirement regime and a new regime: the lowest capital requirement which fully eliminates bank failures.

6.1 Long run effects: comparing steady states

Table 5 summarizes the results for the main exercise conducted in this paper. Though I consider a wide range of levels of the capital requirement, I report results for only five special cases. First is a "low" case, in which $\chi = 1\%$, corresponding to a very lax regime. Second, is $\chi = 8\%$, the benchmark model estimated in Section 4. Third, I report a "medium" case in which $\chi = 16\%$. Twice the current requirement, this level dampens but does not eliminate the externality associated with bank failures. Fourth is the "no failure" case of $\chi = 26\%$, the lowest level at which bank failures are completely eliminated. Finally, I present a "high" case with $\chi = 35\%$ to show what happens when capital requirements are raised beyond the level at which bank failures are eliminated.

I first analyze banks' financing behavior, since this is the first link between a change in capital requirement and aggregate investment. Then, I consider firm outcomes in the aggregate and across lender choices. Next, I document how changing capital requirements affects key business cycle moments of the model economy. Finally, I conclude the long run analysis with a discussion of why the effects of changing capital requirements are found to be small.

6.1.1 Bank financing

Since the capital requirement almost always binds, bank leverage decreases sharply with the capital requirement. While the bank has lower leverage under tighter capital requirements, though, it has higher average capital holdings, replacing external deposit financing with internal financing in order to maintain total lending. As will be discussed below in detail, this is the critical mechanism at work in the model: tighter capital requirements induce the bank to retain more earnings, in order to finance loans with more internal capital. Raising the capital requirement from 8% to 26% raises average bank capital by nearly a factor of 4. Given the reduction in leverage and increase in capital buffer, the rate of bank failure is decreasing in the capital requirement. From the low 1% level to the baseline, the capital requirement does not bind tightly enough to meaningfully change behavior, and failure is unchanged. From the baseline to the medium 16% case, failures are reduced but not fully eliminated. Finally, at a capital requirement of 26% and above, bank failure risk is eliminated.

In order to implement this higher capital level under higher levels of the capital requirement, in addition to holding more capital, the bank issues equity more frequently and in more states of the world. Despite the costs of issuing equity, the tighter capital requirement imposes sharp restrictions on lending in the absence of internal capital, so the bank finds it more worthwhile on the margin to issue equity. Thus, the rate of equity issuance increases by a factor of 2.5 between the baseline and no failure levels of the capital requirement.

Although the bank's monitoring choice is stable across capital requirement levels, there are sizable changes in pricing behavior across capital requirements. As χ is increased from 1% to 8% to 16%, the bank raises its net interest margin by 14 and 11 bps, respectively. When χ is increased further to the level which eliminates failures and beyond, though, the net interest margin falls by 24 bps, just under 4% in percentage terms. What drives this behavior? As the capital requirement is increased, the bank must maintain a larger capital buffer in order to avoid issuing equity. Given this new level of capital and the corresponding reduction in failure risk, the bank optimally chooses to capture a larger share of the loan market. As a result, it chooses to lower its interest rate, and the bank share of total debt increases.

Tightening the capital requirement alters the bank's lending decisions indirectly by altering its marginal cost of lending and valuation of payoffs across states of the world. As suggested by the low Γ factor reported in the benchmark model in Table 4, as well as the surge in bank capital holdings described in Panel A of Table 5, it is reasonable to expect that, in the long run, the transmission of the capital requirement across the balance sheet of the bank is small.

Capital requirement, χ	Low 1%	Baseline 8%	Med. 16%	No fail 26%	High 35%
Panel A: bank financing					
bank leverage (%)	99.0	92.0	84.0	74.0	65.0
average bank capital (e-4)	0.15	0.76	1.48	2.83	3.75
bank failure rate (%)	0.80	0.80	0.44	0.00	0.00
bank equity issuance rate (%)	0.01	0.09	0.18	0.20	0.21
net interest margin (%)	3.75	3.89	4.00	3.76	3.77
monitoring intensity	0.09	0.09	0.09	0.09	0.09
Panel B: aggregate outcomes across all firms					
bank share of debt (%)	27.3	23.4	22.1	27.0	26.7
total debt	0.39	0.39	0.39	0.39	0.39
average interest rate (%)	3.06	3.07	3.07	3.06	3.06
firm leverage (%)	27.8	27.7	27.7	27.8	27.8
chargeoff rate (%)	0.65	0.65	0.65	0.65	0.65
output	1.55	1.55	1.55	1.55	1.55
Panel C: outcomes for bank borrowers					
total debt	0.11	0.09	0.09	0.11	0.11
average interest rate (%)	3.65	3.81	3.90	3.66	3.67
firm leverage (%)	26.1	25.6	25.4	26.1	26.0
chargeoff rate (%)	0.60	0.60	0.59	0.60	0.60
output	1.52	1.51	1.51	1.52	1.52
Panel D: outcomes for non-bank borrowers					
total debt	0.28	0.30	0.30	0.28	0.29
average interest rate (%)	2.81	2.81	2.81	2.81	2.81
firm leverage (%)	28.5	28.5	28.5	28.5	28.5
chargeoff rate (%)	0.67	0.67	0.67	0.67	0.67
output	1.56	1.56	1.56	1.56	1.56

Table 5: **Long run analysis of capital requirement changes**

Notes: All moments are computed by solving the model and simulating it for 10,000 periods, eliminating the first 1,000 to avoid any initial condition bias.

6.1.2 Aggregate investment outcomes: combined and by lender

Panels B and C of Table 5 confirm this intuition. Panel D makes clear that there is no impact whatsoever on firms who choose to borrow from non-bank lenders; the only impact in this regard comes from extensive margin shifts out of bank financing into non-bank financing.

The induced changes to loan pricing are quantitatively small in the model: over the entire range of capital requirements analyzed, the average interest rate paid by firms varies by only 2 bps. Depending on the level of the capital requirement, between 72% and 78% of firms borrow from non-banks, whose interest rates are invariant to the level of the capital requirement. The remaining firms pay higher interest rates, until the "no failure" capital requirement is reached and the bank pursues a lower risk, higher market share strategy. As a result, firms substitute from bank finance into non-bank finance on the margin. Given the modest changes in loan pricing, though, the extent of this substitution is accordingly modest, and the bank share of firms' total debt drops by only 5.2 percentage points over the whole range of capital requirements considered. Consequently, total debt, investment, and output are unchanged.

Turning to the riskiness of aggregate investment, proxied here by chargeoff rates, similar insights apply. Since nothing changes for non-bank borrowers, any change in aggregate default comes from either a reduction in the default rate on bank loans or substitution of firms' borrowing towards non-banks. The first row of Panel C of Table 5 reveals that the bank loan chargeoff rate is constant, though, and so any change must come from substitution. Since the substitution is limited as documented above, the aggregate chargeoff rate is effectively unchanged between the baseline and no failure capital requirements.

6.1.3 Business cycle effects

Table 5 describes the long run average effects of changing the level of the capital requirement, and shows that these changes are mostly small. To complete the picture of the impact of changing capital requirements, Table 6 compares business cycle properties of key model variables between the benchmark (8%) and no failure (26%) levels of the capital requirement.

Similar to the means above, the largest change is with respect to bank capital holdings. Increasing the capital requirement increases the relative volatility of bank capital by 64% and doubles its procyclicality. This result is intuitive: since the bank can rely less on deposits to increase total lending, and since lending more is more desirable in better states of the world, the bank increases its capital in response to positive shocks more readily under a higher capital requirement. Another lens into this dynamic comes from the equity issuance rate: though still strongly countercyclical, it is less so than under benchmark regulation. The bank's net interest margin becomes more volatile and more procyclical.

Panels B and C turn to borrower outcomes in aggregate and conditional on borrowing from the bank. Consistent with the results from Table 5, very little changes about business cycles from the investment side of the model by changing the capital requirement. There are some modest changes for bank borrowers – more volatile debt, less countercyclical interest rates – but even these effects are small. Another potential measure of the riskiness of aggregate investment, the volatility of aggregate output, is actually reduced slightly.

Capital requirement, χ	Baseline 8%		No failure 26%	
Moment	σ_x/σ_y	ρ_{xy}	σ_x/σ_y	ρ_{xy}
Panel A: bank leverage and financing				
average bank capital	0.14	0.23	0.25	0.48
bank equity issuance rate	0.12	-0.96	0.12	-0.88
net interest margin	0.64	0.05	0.90	0.17
monitoring intensity	0.28	0.99	0.25	0.93
Panel B: aggregate outcomes across all firms				
bank share of debt	0.26	0.31	0.83	0.41
total debt	1.72	1.00	1.72	1.00
average interest rate	0.08	-0.99	0.08	-0.98
firm leverage	0.96	1.00	0.95	1.00
chargeoff rate	0.02	-0.36	0.02	-0.36
output	1.02	1.00	1.01	1.00
Panel C: outcomes for bank borrowers				
total debt	0.53	0.97	0.70	0.86
average interest rate	0.11	-0.96	0.12	-0.87
firm leverage	0.98	1.00	0.99	0.99
chargeoff rate	0.02	-0.35	0.02	-0.35
output	0.98	1.00	0.99	0.99

Table 6: **Impact of capital requirements on business cycles: select moments**

Notes: All moments are computed by solving the model and simulating it for 10,000 periods, eliminating the first 1,000 to avoid any initial condition bias. Moments reported are for log HP-filtered data, with a smoothing parameter of 1600.

6.1.4 Taking stock: long run effects of raising capital requirements

Why are the effects small? The results of Tables 5 and 6 suggest that tighter capital requirements greatly reduce the risk of bank failure while having minimal impacts on aggregate default and investment. Two main results contribute to this aggregate finding. First, given the bank's incentive to accumulate capital away from low levels of net worth for which its lending decisions are distorted, in the long run the bank endogenously moves away from the tighter constraint. Second, any cost of reduced investment and output from bank-borrowing firms is offset by the non-bank sector, and the increase in the riskiness of loans from this substitution is small. This latter result follows from the small estimated degree of moral hazard on the part of firms in the model.

Using the language of financing wedges and elasticities, changing the capital requirement has little impact on the equilibrium bank financing wedge, $\epsilon(R_B, b_B)$.[22] What delivers this result? For a given level of capital, the financing distortion $\xi'(E)$ is higher under the higher capital requirement. However, the level of this measure does not directly matter, but rather the intertemporal distortion it induces, reflected in the Γ factor from equations (21) and (22). Even though $\xi'(E)$ increases on average, the ratio $\xi'(E')/\xi'(E)$ changes little, and so there is almost no distortion in the bank's decisions.

What would it take to make the effects large? Another lens into the results above is to consider what about the model would have to change in order to get large effects in this analysis. I consider two answers: one purely quantitative, and one theoretical.

First, from a quantitative perspective, the degree of moral hazard in the model is quite small (low θ). Therefore, even though the cost to the bank of mitigating moral hazard is low on a per unit basis, the benefits of doing so are small. As a result, the bank competes on price with the competitive non-bank sector, and the equilibrium outcomes under the two loan contracts are similar. If the extent of moral hazard were larger, this effect could be made larger, with implications for both the riskiness and quantity of aggregate investment.

Second, theoretically, the competition for loan volume between the bank and non-banks is relatively intense in the model along three dimensions. The first has to do with the low degree of moral hazard in the economy described above. The second comes from the fact that since non-banks have deep pockets, the bank is competing with a set of agents compared to which it is relatively financially constrained. If this assumption were relaxed, there could be larger effects; however, even with a richer non-bank sector, it is difficult to get around the disciplining effect of the simple, competitive alternative of the bond market. Third, all banks in the model can in principle substitute between bank and non-bank lending. If the bank was a true monopolist at least in some sector of the economy, it could in principle make this sector "bear the brunt" of the increase in capital requirements while still competing tightly in the other sectors. Still, though, if these constraints are large and lending to this bank-dependent sector is profitable, it is reasonable to expect another type of lender to step into this market.

6.1.5 Welfare

In this section, I consider the impacts of raising capital requirements directly on welfare. Given my assumption of universal risk neutrality, any welfare analysis must account for risk

[22] Table C.2 in Appendix C.3 shows the actual analogs of the financing variables from Table 4 across levels of the capital requirement.

in an indirect way. Given this fact, in Table 7 I provide a disaggregated view of total welfare in the economy across all agents.

For firms, I consider three measures of total welfare. First, I consider firms' ex ante value before their choice of lender, given by equation (10). Then, I consider the value to a firm conditional on a choice of lender, given by (6). The results are consistent with the aggregate statistics reported above. Total firm welfare is weakly increasing the capital requirement, but the effect appears only in the fourth decimal place. By assumption, welfare is unchanged for firms choosing to borrow from the bank, and so the total increase is attributable to the increase in welfare for bank borrowers. This effect is positive, but very small in magnitude.

Capital requirement, χ	**1%**	**8%**	**16%**	**26%**	**35%**
firm welfare, ex ante	1.1556	1.1556	1.1556	1.1557	1.1557
firm welfare, bank borrowers	1.1548	1.1546	1.1546	1.1548	1.1548
firm welfare, non-bank borrowers	1.1554	1.1554	1.1554	1.1554	1.1554
bank welfare, total	0.0019	0.0089	0.0166	0.0310	0.0404
bank welfare, per unit of capital	1.2588	1.1743	1.1184	1.0959	1.0782
expected tax cost per period (e-4)	-0.9793	-0.5237	-0.2096	0	0
tax cost, conditional on bank failure	-0.0136	-0.0073	-0.0047	0	0
Total	1.1574	1.1645	1.1721	1.1867	1.1961

Table 7: **Welfare effects of capital requirement changes**

Notes: All moments are computed by solving the model and simulating it for 10,000 periods, eliminating the first 1,000 to avoid any initial condition bias. The total welfare metric sums ex ante firm welfare, total bank welfare, and the expected tax cost per period.

Turning to the bank, even though the constraint is tightened, bank value is higher on average under higher capital requirements. This stems from the fact that the bank is forced to accumulate capital, which represents a cheap source of internal financing. This reduces losses associated with failure and the costs associated with equity issuance. Although this value increase is sizable in absolute terms, the bank becomes much less valuable per unit of capital.

Finally, consistent with the results documented above for bank failures, the losses due to bank failures from the tax cost (23) decline both in expectation, and in realization conditional on bank failure. For capital requirements above 26%, these costs are exactly zero. Even for low levels of the capital requirement, these costs are extremely low in expectation. In addition to lowering the risk of bank failures, though, it is worthwhile to note that higher capital requirements also dampen the pain of bank failures by promoting larger capital buffers at the bank.

6.2 Transitions between capital requirements

Section 6.1 considers different equilibria under a range of capital requirements. While this offers important insights into the costs and benefits of increasing capital requirements, a critical concern for implementation of regulatory changes is how the economy adjusts over the transition from one regulatory regime to another. In principle, a too-costly transition could undo the long-run gains from increasing capital requirements. Furthermore, given that the key mechanism underlying the small long run effects of changing capital requirements in the analysis above was the accumulation of bank capital, it is worthwhile to consider the exact process by which the bank would perform this capital accumulation. This section analyzes this transition.

I consider two possible transition path in Figure 7. Both transitions occur with 20 periods (5 years) between the announcement of the change and the full implementation of the new capital requirement, and both raise the capital requirement from the current Basel minimum of 8% to the level from Section 6.1 that was shown to eliminate bank failures in the model: 26%. The only difference between these experiments is that the first ("sudden phase-in") features a one-time adjustment from 8% to 26% at the implementation date, whereas the second experiment ("gradual phase-in") increases the capital requirement linearly between the announcement date and the final implementation date.

The top three panels show how the bank changes its financing policies over the course of the transition. The middle three panels show the impact on total output, total debt (investment), and the composition of debt. The bottom three panels show how the bank changes its contract terms, and how these changes in policy affect the riskiness of investment.

Regardless of the specific transition path, consistent with the results from the preceding sections the economy converges to a steady state with a much higher level of bank capital, just over 250% higher than under the baseline case. Deposits drop by 7 pp relative to the baseline, while total debt and output increase by 0.1% and 0.4% respectively. The bank share of debt increases by 17%, and the interest rate spread the bank charges declines. Monitoring intensity increases modestly, and the chargeoff rate increases by 1%.

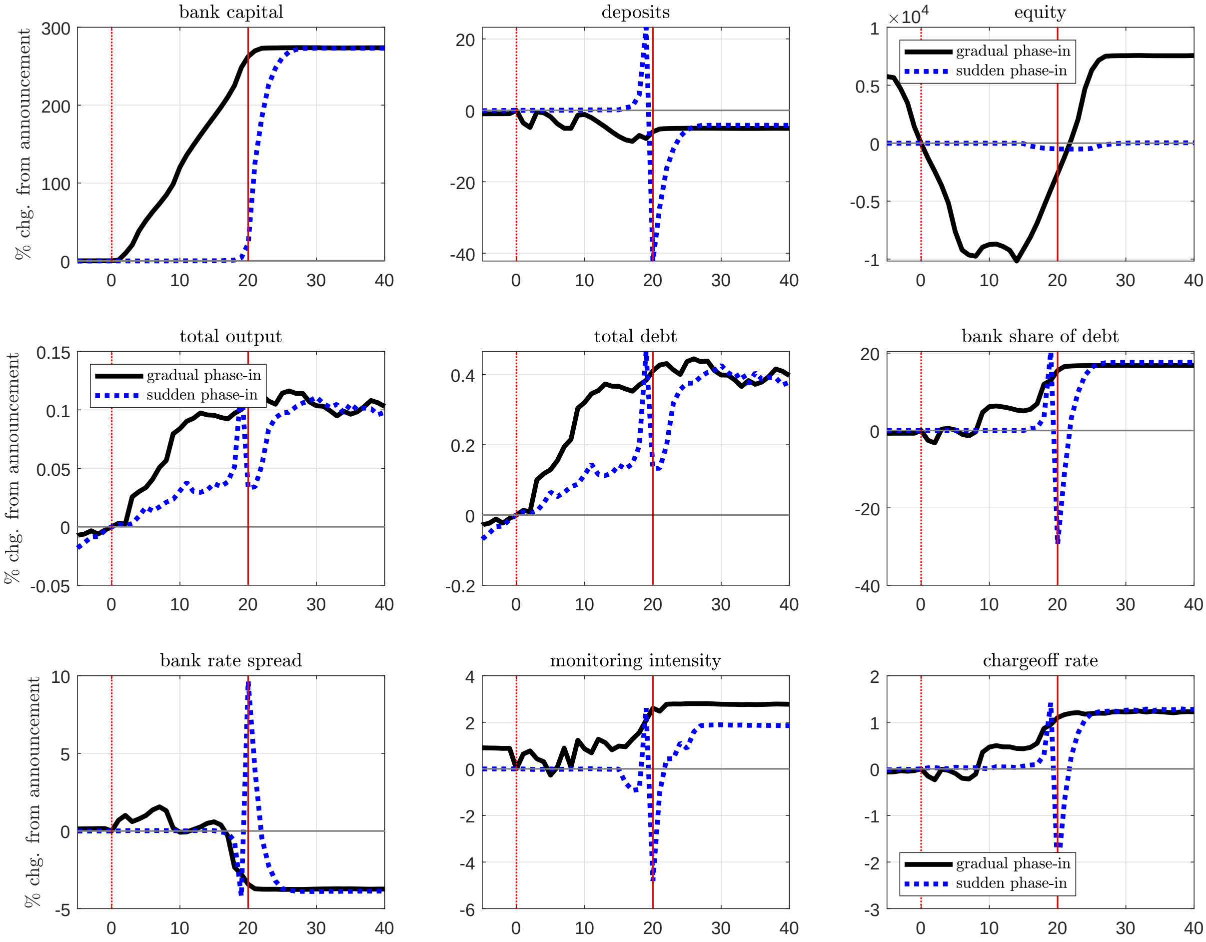

Figure 7: **Transition path between capital requirement regimes**

Notes: This figure shows the behavior of model objects over the transitions. Each point is the average across 100,000 simulated transition paths of the model to average over idiosyncratic sequences of the aggregate state process. In the "gradual" phase-in (black), the capital requirement is increased linearly over the 20 periods between announcement (date 0) and implementation (date 20). In the "sudden" phase-in (blue), the capital requirement is held constant at 8% until the implementation date, when it is suddenly increased to 26%.

Under the sudden phase-in, the bank does nothing in the lead up to the implementation of the higher capital requirement. Then, upon implementation, it sharply increases its capital base over the span of less than ten periods to the new optimal level. It does this by cutting loan rates relative to non-bank rates by almost 5% the period before implementation, thereby attracting a share of total lending 20% higher than its average. The bank retains earnings from this one-time "lending holiday," then unwinds these policies over the next several periods. As a result, even though the transition is slated to happen between periods 0 and 20, all the action effectively happens between periods 19 and 25. Crucially, although the bank issues some equity in the periods around the implementation date, the quantity is small, leading to minimal distortions.

In contrast, when the implementation is gradual, the bank adapts to the new capital requirement regime in a very different way. First, the increase in capital happens gradually, rising in tandem with the level of χ. As a result, the bank achieves the new level of capital by the implementation date, and all the action of the transition happens between periods 0 and 20. Since it must adjust to a new slightly higher capital requirement each period, however, the bank is forced to deviate from its steady state policies at each date along the transition. As it builds up its capital base, it does so while constrained from issuing more deposits, and so it must turn to greater equity issuance, which is costly. Interestingly, there are several non-monotonicities in the gradual transition path. These occur because as the capital requirement increases, there are several discrete thresholds which impact bank failure risk, and therefore cause non-continuous changes in bank policies. For example, tightening the capital requirement at first causes deposits to drop, but then to increase again once the bank decides to take a larger share of the lending market. This happens three times over the course of the transition, creating a somewhat more volatile path on average with regards to bank financing. Since output and investment are weakly increasing in the capital requirement, however, under the gradual transition the gains in these variables happen earlier.

7 Conclusion

In this paper, I have presented a tractable dynamic framework to analyze the effects of bank capital requirements. Motivated by the modern financial system in the U.S., borrowers may obtain financing from non-bank lenders, modeled to resemble a competitive bond market, which comprises the majority of non-bank financing in the U.S.. The model features (i) a choice between lenders for firms; (ii) a distinction between these lenders which creates a unique role for banks (monitoring); and (iii) bank risk-taking incentives, and therefore a role for bank regulation. There is two-sided moral hazard, with firms facing a standard agency friction which limits investment and a bank which can shift risk to taxpayers given its limited liability and ability to take in insured deposits. The bank has market power, but must compete for loans with the non-bank sector. Finally, the bank is subject to a financial friction in the form of costly equity issuance which impacts its financing and lending decisions.

The key mechanisms in the model are as follows. The agency friction within firms yields under-investment, the extent of which varies with respect to contract terms and the aggregate state of the world. The bank may mitigate the severity of this agency friction by monitoring firms at a cost. In this sense, bank lending may have value for reducing the riskiness of aggregate investment. The bank sets its contract terms, and therefore its net impact on the quantity and riskiness of aggregate investment, by weighing three factors. First, costly equity issuance distorts its valuation of payoffs under certain contracts across states of the world. Second, a capital requirement limits the extent to which it can finance loans with cheap deposits. Third, the bank actively competes for loans, since borrowers may substitute to other lenders.

After taking the model to the data and validating its performance for key links between firm financing, bank capital, and investment, I use this framework to map out the impacts of increasing bank capital requirements. By limiting bank leverage, tighter capital requirements provide an incentive for the bank to maintain a larger capital buffer and issue more equity given financing shortfalls on the margin. I show that by raising the capital requirement to 26%, bank failures can be completely eliminated along the equilibrium path. The cost in terms of reduced quantity and increased riskiness of investment is effectively zero.

This result is the product of two key forces. First, the bank can readily increase its capital stock by retaining earnings in order to meet a higher capital requirement in the long run. Second, and more subtly, the discipline imposed on the bank's equilibrium lending contract by the non-bank sector is sufficiently strong that the bank does not have latitude to drastically raise interest rates and drive large shifts in lending and investment. Ultimately, then, the analysis confirms the benefits of raising capital requirements on banks, even in the presence of an alternative lending sector which is unregulated and lends less efficiently. Analyzing the transition path between capital requirement regimes suggests that there are no significant short term costs which can offset these long run gains.

This paper contributes to the literature which studies the effects of banking capital requirements. Specifically, it highlights the tradeoff between making one lending sector of the economy safer, while potentially pushing lending into another sector. For simplicity of exposition of the core ideas, however, this paper has several limitations which create room for fruitful future research. For example, one could analyze different regulatory structures, such as countercyclical rather than flat capital requirements and optimal phase-ins of capital requirements. Moreover, the non-bank sector in the model can be enriched in many ways, and the firm sector can be extended to include heterogeneity. I leave these and other questions for future research.

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Appendix for "Macroprudential Capital Requirements with Non-Bank Finance"

A Model Appendix

A.1 Proofs

A.1.1 Proof of Proposition 1

Optimality The value associated with borrowing under contract (q, m) in state z is given by (6). Since $q \leq \overline{q} < 1$ and firms are risk neutral, borrowing only occurs if investment exceeds internal capital: I focus only on this case (when $b > 0$). The budget constraint must bind, and so the problem can be expressed as a single, unconstrained optimization in terms of the loan size. This optimization yields the first order condition

$$\frac{d\psi(\overline{x}(b;q,m,z))}{db}R(b;q,z) + \psi(\overline{x})\frac{dR(b;q,z)}{db} = 0.$$

Rearranging terms yields

$$\frac{1}{R}\frac{dR}{db} = -\frac{1}{\psi}\frac{d\psi(\overline{x}(b;q,m,z))}{\partial b}$$

and multiplying both sides by b establishes that $\epsilon(R, b) = -\epsilon(\psi, b)$. The signing must be true at an optimum since $\partial R/\partial b < R/b$, which much be true at any optimum.

Characterizing the elasticity In order to characterize the elasticity term, first apply the chain rule: $\epsilon(\psi, b) = \epsilon(\psi, \overline{x})\epsilon(\overline{x}, b)$. Then, use standard elasticity calculation rules to obtain

$$\begin{aligned}
\epsilon(\psi,\overline{x}) &= \epsilon(1-\kappa+\kappa G(\overline{x}),\overline{x}) \\
&= \frac{\kappa G(\overline{x})}{\psi(\overline{x})}\epsilon(\kappa G(\overline{x}),\overline{x}) \\
&= \frac{\kappa \overline{x} g(\overline{x})}{\psi(\overline{x})} \\
\epsilon(\overline{x},b) &= \epsilon\left(m+\left(1+\kappa\frac{1-\theta}{\theta}\right)\frac{R(b;q,z)}{b},b\right) \\
&= \frac{\left(1+\kappa\frac{1-\theta}{\theta}\right)\frac{R(b;q,z)}{b}}{\overline{x}}\epsilon\left(\left(1+\kappa\frac{1-\theta}{\theta}\right)\frac{R(b;q,z)}{b},b\right) \\
&= \frac{\overline{x}-m}{\overline{x}}(\epsilon(R,b)-1), \qquad \text{(A.1)}
\end{aligned}$$

Combining these expressions and using the first order condition,

$$\epsilon(R,b) = -\epsilon(\psi,b) = \frac{\kappa g(\overline{x})(\overline{x}-m)}{\psi(\overline{x})}(1-\epsilon(R,b)).$$

Rearranging to isolate the $\epsilon(R, b)$ terms yields the second equality in (7). *Q.E.D.*

A.1.2 Proof of Proposition 2

Ex ante value and loan demand The first two results in equations (9) and (10) follow directly from the discrete choice literature (for example, Rust (1987); McFadden (1973)). The derivation of the firm value expression (10) rests on the definition

$$w_F(\mathcal{C}, z) \equiv \int v_F(\nu; \mathcal{C}, z) dF(\nu)$$

The total loan demands simply multiply the mass of firms choosing a given lender and the firm-specific demand at that lender.

Relationship between loan share and lender-specific value The share of firms choosing bank (non-bank) lending is ℓ $(1-\ell)$, and firms of these types choose b_B and b_N as their loan sizes respectively. Also, observe that

$$\frac{\partial \log \ell}{\partial \zeta} = \frac{1}{\zeta} \frac{\exp\{(v_N - v_B)/\zeta\}}{1 + \exp\{(v_N - v_B)/\zeta\}} = \frac{1-\ell}{\zeta^2}(v_N - v_B)$$

which is negative (positive) if $v_B > v_N$ $(v_B < v_N)$. *Q.E.D.*

A.1.3 Proof of Proposition 3

Loan share elasticities To ease notation, I use the same shorthand as in the main text where convenient. To compute the elasticity of loan shares with respect to contract terms, use the expression for loan demand (9) and focus on the bank loan price to find that:

$$\begin{aligned}
\epsilon(\ell, q_B) &= \epsilon\left(\left[1 + \exp\left\{\frac{v_N - v_B(q_B, m)}{\zeta}\right\}\right]^{-1}, q_B\right) \\
&= -\epsilon\left(1 + \exp\left\{\frac{v_N - v_B(q_B, m)}{\zeta}\right\}, q_B\right) \\
&= -\frac{\exp\left\{\frac{v_N - v_B(q,m)}{\zeta}\right\}}{1 + \exp\left\{\frac{v_N - v_B(q,m)}{\zeta}\right\}} \epsilon\left(\exp\left\{\frac{v_N - v_B(q_B, m)}{\zeta}\right\}, q_B\right) \\
&= -(1-\ell)\frac{v_N - v_B(q_B, m)}{\zeta} \epsilon\left(\frac{v_N - v_B(q_B, m)}{\zeta}, q_B\right) \\
&= (1-\ell)\frac{v_B(q_B, m)}{\zeta} \epsilon(v_B, q_B) \qquad \text{(A.2)}
\end{aligned}$$

A similar calculation for monitoring intensity implies that

$$\epsilon(\ell, m) = (1-\ell)\frac{v_B}{\zeta}\epsilon(v_B, m),$$

and so in order to compute the elasticity of the bank loan share we need to compute the elasticity of the value of borrowing from the bank with respect to the relevant contract term.

Using the firm's objective function (6), and suppressing the dependence of the elasticities on contract terms,

$$\begin{aligned}\epsilon(v_B, q_B) &= \epsilon(\psi, q_B) + \epsilon(R, q_B) \\ &= \overline{\epsilon}(\psi, q_B) + \epsilon(\psi, b)\epsilon(b, q_B) + \overline{\epsilon}(R, q_B) + \epsilon(R, b)\epsilon(b, q_B) \\ &= \overline{\epsilon}(\psi, q_B) + \overline{\epsilon}(R, q_B) + \epsilon(b, q_B)\left(\epsilon(\psi, b) + \epsilon(R, b)\right) \\ &= \overline{\epsilon}(\psi, q_B) + \overline{\epsilon}(R, q_B) \end{aligned} \tag{A.3}$$

where the second line uses the definition of the direct elasticities

$$\overline{\epsilon}(\psi, q) \equiv \epsilon(\psi, \overline{x})\frac{q}{\overline{x}}\frac{\partial \overline{x}}{\partial q} \text{ and } \overline{\epsilon}(R, q) \equiv \frac{q}{R}\frac{\partial R}{\partial q}$$

and the last equality comes from the firm's optimal loan choice condition (7). Similarly, the elasticity of value with respect to monitoring is $\epsilon(v_B, m) = \overline{\epsilon}(\psi, m)$, which can be obtained using the same derivation as in (A.3) and observing that monitoring has no direct effect on expected firm returns conditional on success.

Finally, observe that $\overline{\epsilon}(\psi, q) = \epsilon(\psi, \overline{x})\overline{\epsilon}(\overline{x}, q)$. The first term can be computed using the results in (A.1) from the proof of Proposition 1. To compute the second,

$$\begin{aligned}\overline{\epsilon}(\overline{x}, q) &= \overline{\epsilon}\left(m + \left(1 + \kappa\frac{1-\theta}{\theta}\right)\frac{R(b; q, z)}{b}, q\right) \\ &= \frac{\left(1 + \kappa\frac{1-\theta}{\theta}\right)\frac{R(b;q,z)}{b}}{\overline{x}}\overline{\epsilon}\left(\left(1 + \kappa\frac{1-\theta}{\theta}\right)\frac{R(b; q, z)}{b}, q\right) \\ &= \frac{\overline{x} - m}{\overline{x}}\overline{\epsilon}(R, q)\end{aligned}$$

Again from (A.1), we know

$$\epsilon(\psi, \overline{x})\frac{\overline{x} - m}{\overline{x}} = \frac{\epsilon(R, b)}{1 - \epsilon(R, b)},$$

and so combining this expression with (A.3) delivers equation (13) in the text. A similar calculation reveals that $\overline{\epsilon}(\overline{x}, m) = m/\overline{x}$, and so

$$\begin{aligned}\overline{\epsilon}(\psi, m) &= \epsilon(\psi, x)\frac{m}{\overline{x}} \\ &= \frac{\epsilon(R, b)}{1 - \epsilon(R, b)}\frac{\overline{x}}{\overline{x} - m}\frac{m}{\overline{x}},\end{aligned}$$

yielding the result in equation (14).

To compute the elasticity of the loan share with respect to the non-bank price, we can proceed in a similar manner to (A.2) above:

$$\begin{aligned}
\epsilon(\ell, q_N) &= \epsilon\left(\left[1+\exp\left\{\frac{v_N(q_N,0)-v_B}{\zeta}\right\}\right]^{-1}, q_N\right) \\
&= -\epsilon\left(1+\exp\left\{\frac{v_N(q_N,0)-v_B}{\zeta}\right\}, q_N\right) \\
&= -\frac{\exp\left\{\frac{v_N(q_N,0)-v_B}{\zeta}\right\}}{1+\exp\left\{\frac{v_N(q_N,0)-v_B}{\zeta}\right\}}\epsilon\left(\exp\left\{\frac{v_N(q_N,0)-v_B}{\zeta}\right\}, q_N\right) \\
&= -(1-\ell)\frac{v_N(q_N,0)-v_B}{\zeta}\epsilon\left(\frac{v_N(q_N,0)-v_B}{\zeta}, q_N\right) \\
&= -(1-\ell)\frac{v_N(q_N,0)}{\zeta}\epsilon(v_N, q_N).
\end{aligned}$$

The remainder of the calculation follows exactly as for the bank loan price elasticity above. Additionally, note the relation from the value function (10): $v_B/\zeta = w_F/\zeta + \log \ell$. Likewise, $v_N/\zeta = w_F/\zeta + \log(1-\ell)$.

Success probability elasticities The success probability elasticities simply combine terms already computed to this point:

$$\begin{aligned}
\epsilon(\psi, q) &= \epsilon(\psi, \overline{x})\overline{\epsilon}(\overline{x}, q) + \epsilon(\psi, \overline{x})\epsilon(\overline{x}, b)\epsilon(b, q) \\
\epsilon(\psi, m) &= \epsilon(\psi, \overline{x})\overline{\epsilon}(\overline{x}, m) + \epsilon(\psi, \overline{x})\epsilon(\overline{x}, b)\epsilon(b, m),
\end{aligned}$$

and so we can obtain the results in equations (15) and (16) immediately. $Q.E.D.$

A.1.4 Proof of Proposition 4

Taking as given the premise from the text that the capital requirement always binds and that we can ignore the max operator in the bank's capital accumulation equation, we obtain the following unconstrained optimization in two variables:

$$\begin{aligned}
V(K;z) &= \max_{q,m} \xi\left(K-(c(m)-(1-\chi))qL(q,m)\right) \\
&\quad + \overline{q}\mathbb{E}\left[V\left(\lambda' + L(q,m)\left(\iota + (1-\iota)(1-\psi(\overline{x}(q,m))\pi(z')) - \frac{q}{q_D}(1-\chi)\right); z'\right)\right]
\end{aligned} \tag{A.4}$$

I further suppress dependence on the aggregate state except when absolutely necessary. Recognizing the envelope condition $V'(K;z) = \xi'(E)$, the optimality conditions with respect to q and m, respectively, are

$$
\begin{aligned}
&[c(m)-(1-\chi)]\xi'(E)\left[q\frac{dL(q,m)}{dq}+L(q,m)\right]\\
=&\overline{q}\mathbb{E}\left[\xi'(E')\left(\frac{dL(q,m)}{dq}\left(\iota+(1-\iota)\psi(\overline{x})\pi(z')-\frac{q}{q_D}(1-\chi)\right)\right.\right.\\
&\left.\left.+L(q,m)\left((1-\iota)\pi(z')\frac{d\psi(\overline{x})}{dq}-\frac{1-\chi}{q_D}\right)\right)\right]
\end{aligned}
$$

and

$$
\begin{aligned}
&q\xi'(E)\left[c'(m)L(q,m)-(1-\chi-c(m))\frac{dL(q,m)}{dm}\right]\\
=&\overline{q}\mathbb{E}\left[\xi'(E')\left(\frac{dL(q,m)}{dm}\left(\iota+(1-\iota)\psi(\overline{x})\pi(z')-\frac{q}{q_D}(1-\chi)\right)\right.\right.\\
&\left.\left.+L(q,m)(1-\iota)\pi(z')\frac{d\psi(\overline{x})}{dm}\right)\right]
\end{aligned}
$$

Simplifying these expressions, and using the elasticities defined above, we obtain equations (21) and (22) in the main text. *Q.E.D.*

A.2 Bank problem with no financing constraints

In a version of the benchmark model absent financing frictions (costly equity, risk-shifting, limited liability, capital requirements), the problem of the bank would be

$$\max_{q,m} L(q,m)\left[\overline{q}\left((1-\iota)\psi(\overline{x}(q,m))\overline{\pi}+\iota\right)-c(m)q\right] \tag{A.5}$$

where the first term in brackets denotes the discounted expected return per loan, and the second term denotes the per unit cost of lending. I also abbreviate $\overline{\pi}\equiv\mathbb{E}\left[\pi(z')|z\right]$. Taking first order conditions with respect to each contract terms yields

$$
\begin{aligned}
\frac{dL(q,m)}{dq}\left[\overline{q}\left((1-\iota)\psi(\overline{x}(q,m))\overline{\pi}+\iota\right)-c(m)q\right]+L(q,m)\left[\overline{q}(1-\iota)\overline{\pi}\frac{d\psi(\overline{x}(q,m))}{dq}-c(m)\right] &= 0\\
\frac{dL(q,m)}{dm}\left[\overline{q}\left((1-\iota)\psi(\overline{x}(q,m))\overline{\pi}+\iota\right)-c(m)q\right]+L(q,m)\left[\overline{q}(1-\iota)\overline{\pi}\frac{d\psi(\overline{x}(q,m))}{dm}-c'(m)q\right] &= 0
\end{aligned}
$$

Multiplying the first and second equations above by q/L and m/qL, respectively, and rearranging terms delivers familiar elasticity conditions:

$$c(m)(1+\epsilon(L,q)) = \frac{\overline{q}}{q}\psi(\overline{x})(1-\iota)\overline{\pi}(\epsilon(\psi,q)+\epsilon(L,q)) + \frac{\overline{q}}{q}\iota\epsilon(L,q) \tag{A.6}$$

$$c(m)(\epsilon(c,m)+\epsilon(L,m)) = \frac{\overline{q}}{q}\psi(\overline{x})(1-\iota)\overline{\pi}(\epsilon(\psi,m)+\epsilon(L,m)) + \frac{\overline{q}}{q}\iota\epsilon(L,m) \tag{A.7}$$

Equations (A.6) and (A.7) are the frictionless analogs of equations (21) and (22) in the main text.

B Data Appendix

B.1 Definitions of data moments by source

B.1.1 QFR

Bank share of debt Sum of short term bank (total) debt, long term bank (total) debt maturing in less than one year, and long term bank (total) debt maturing in more than one year.

Firm leverage Ratio of total debt to total assets.

Investment Quarter over quarter change in net property, plant, and equipment, plus depreciation

B.1.2 Call Reports

Bank leverage Ratio of total liabilities to total assets.

Chargeoff rate Since all lending in the model is business lending, the relevant chargeoff rate is the C&I loan chargeoff rate. This is computed as the total C&I dollars charged off, less total C&I dollars recovered, divided by total C&I loans.

Net interest margin Difference between loan returns (R_ℓ) and the cost of deposit funding (R_d). Following Corbae and D'Erasmo (2013), these are computed as

$$\begin{aligned} NIM &= R_\ell - R_d \\ R_\ell &= \left(1+\frac{\text{interest income on C\&I loans}}{\text{total C\&I loans}}\right)/\,(1+\text{inflation rate})-1 \\ R_d &= \left(1+\frac{\text{interest expense on deposits}}{\text{deposits}}\right)/\,(1+\text{inflation rate})-1 \end{aligned}$$

Bank failure rate Ratio of total exits by failure in a given quarter divided by the total number of banks in that quarter.

Bank equity issuance rate Ratio of newly issued equity to total assets of the bank, and then average this metric across banks. For the vast majority of banks in a given quarter, this number is equal to zero.

B.1.3 Flow of Funds and Macro data

Investment Total capital expenditures for non-financial corporate business.

Non-bank loan spreads On the non-bank side, I focus only on corporate bonds for two reasons. First, data availability on loan returns for other non-bank financial institutions is scarce. Second, corporate bonds map most clearly into the unmonitored lending of my model, since there is a well known "tragedy of the commons" under which no individual bondholder monitors borrowers. I use the corporate bond spread for Moody's Aaa-rated firms everywhere unless otherwise stated.

GDP Output is measured in real chained 2000 dollars.

Inflation All deflating of nominal variables is done using the Consumer Price Index (CPI).

Risk-free rate I use as a benchmark the interest rate on the 1-year Treasury bill.

B.2 Definitions of model moments

Bank share of debt Total debt D sums bank and non-bank debt, and the bank share S is the ratio of bank to total debt:

$$D = q_B \ell b_B + q_N(1-\ell)b_N \text{ and } S = \frac{q_B \ell b_B}{D}$$

Bank leverage Ratio of total bank liabilities, $q_D D$, to total bank assets, $q_B L_B$.

Chargeoff rate and default rate The default rate for lending of type i in period $t+1$ conditional on a realization z' is

$$DR_i(z') = 1 - \psi(\overline{x})\pi(z'),$$

and the chargeoff rate adjusts this quantity for recovery: $CR_i(z') = (1-\iota)DR_i(z')$.

Net interest margin The bank's total cost of lending is $1/c(m)q_B$, with the cost of funds $1/q_D$. For comparability with the data, given the quarterly time horizon of the model, I annualize each of these rates and take their difference.

Bank failure rate Given a simulation of length T with F realizations of $K < 0$, I define the bank failure rate as F/T.

	Loan Growth		Chargeoff Rate	
	C&I	Total	C&I	Total
	(1)	(2)	(3)	(4)
deposits	0.548***	0.540***	-0.002	-0.002***
	(0.021)	(0.021)	(0.015)	(0.001)
non-deposit debt	0.572***	0.607***	0.058	-0.007
	(0.061)	(0.053)	(0.075)	(0.004)
equity	0.184***	0.203***	-0.025	-0.017***
	(0.016)	(0.012)	(0.023)	(0.001)
retained earnings	-0.004***	-0.004***	-0.002	-0.002***
	(0.001)	(0.001)	(0.003)	(0.000)
Bank FE	Y	Y	Y	Y
Quarter FE	Y	Y	Y	Y
Controls	Y	Y	Y	Y
N	367,716	373,397	25,825	373,441
Adjusted R^2	0.036	0.264	0.009	0.096

Table B.1: **Panel regressions for bank loan growth and chargeoffs**

Notes: The results reported are estimated on a sample of banks from the Call Reports. Standard errors are unclustered. *** denotes significance at the 1% level.

Bank equity issuance rate I define the equity issuance rate in a period as the ratio of $-E \times \mathbf{1}[E < 0]$ to total bank assets, $q_B L_B$.

B.3 Additional empirical analysis

In this section, I estimate a series of panel regressions in order to corroborate the coarse correlations from Panel A of Table 2 in the main text. Specifically, for bank i in quarter t, I estimate $y_{i,t} = \alpha_i + \alpha_t + \beta X_{i,t} + \epsilon_{i,t}$,where $y_{i,t}$ is the log change in total lending, the log change in C&I lending, the chargeoff rate on all loans, or the chargeoff rate on C&I loans. $X_{i,t}$ is a vector of the log change in deposits, non-deposit debt, equity, or retained earnings. I find that the "pecking order" of loan growth comovements with financing variables presented in Table 2 is preserved when controlling for bank and time fixed effects in Table B.1. Moreover, consistent with the quantitative analysis of the model, I find that changes in chargeoff rates are essentially orthogonal to changes in financing variables in the cross-section of banks.

C Quantitative Appendix

C.1 Computational algorithm

1. **Initialization.** Declare all model parameters, grid lengths N_x and grid bounds $[\underline{x}, \overline{x}]$ for variables x analyzed over discrete grids.

2. **Solve for equilibrium non-bank and deposit prices.** In equilibrium, q_D satisfies equation (18) for all (K, z). For non-bank loan prices, use bisection to find $q_N(z)$ for all states z according to equation (17). At each point in this bisection, use golden section search to determine the optimal loan size $b_N(z)$ which solves (6) at the given price.

3. **Solve the bank problem.** The solution to the bank problem can be divided into two phases: computing loan demand and loan repayment for each possible contract, and solving for optimal contracts and financing policies:

   (a) **Compute loan demand and repayment.** For each m and q on a coarse grid, determine the optimal loan size $b_B(q, m; z)$ which solves (6) at the given m, q, and z. Use this to compute the firm's value under the contract according to (6), and then use (9) to determine the bank loan share and therefore total loan demand. Use (4) and (5) to compute the repayment probability associated with each contract. Then, interpolate these values over a finer grid of contract terms. Note that these responses need only be computed once, as the response conditional on a contract is invariant to the state of the bank when it chooses the contract.

   (b) **Solve the value function.** Taking the loan demands and repayment probabilities across contract terms computed above as given, solve for the optimal financing policies and contract choices across all levels of K and z. This amounts to solving the functional equation (20) over a grid of points.

4. **Simulate the model and compute moments.** Starting from an initial condition, simulate a sample from the model for T periods and compute moments. Simulate the model for T periods. This involves drawing T shocks for the z and λ processes and using the decision rules of the bank to map out the evolution of bank capital. Drop T_0 periods to avoid any initial condition bias. Use the sample to compute any desired moments.

C.2 Parameter sensitivity analysis

In this subsection, I provide a sensitivity analysis of the targeted model moments from Table 1. The results are presented in Table C.1 below. Each column entry corresponds to the equilibrium model moments which result from increasing the indicated variable from its benchmark value in Table 1 by 1%.

Raising the variance of the extreme value shocks increases the net interest margin of the bank and decreases the bank share of debt, with little impact on other model moments. Increasing the mean of the private benefit shocks makes bank lending more valuable by increasing the role of monitoring, and so the net interest margin ticks up along with the chargeoff rate on bank loans; the bank share of debt declines, as does total firm leverage. Increasing κ means that managers exert more control over the eventual success probability of the project. To the extent that managers weigh the proceeds from firm profits highly, this implies that projects become less risky, reducing the bank share as well as all measures of bank market power and investment risk. Increasing θ means moral hazard is more severe, working in the opposite direction.

Turning to the model technologies, almost every moment is highly sensitive to the returns to scale α. Raising this parameter even slightly implies a sharp increase in firm leverage and a sharp reduction in riskiness relative to overall productivity. Combined, these forces reduce the overall value of the bank, and the bank share decreases sharply. To compensate, the bank more stridently for quantity, lowering its spread over the non-bank rate. The bank almost never fails or issues equity in this case. Increasing the bank's monitoring cost increases the net interest margin by raising the unit cost of lending, and also lowers the bank share and raises the persistence of total debt.

Finally, I examine the effects of altering the aggregate shock processes. Raising the mean of the z process acts similarly to increasing the returns to scale of the firm, with one caveat: it makes firm scale more sensitive to the aggregate state. Furthermore, since the effect is smaller, the bank still chooses to maintain a relatively large market share, unlike in the high α case. Increasing the persistence of the process leads to more volatile GDP, since lenders price loans accounting for the increased likelihood that the state remains unchanged, leading to larger swings when the state does change. Increasing volatility leads to similar results, with a pronounced decline in the cyclicality of the bank share. Increasing the base probability of success, $\overline{\pi}$, leads to a sharp drop in interest rates, a decline in the bank share, and an increase in firm leverage. Lastly, changing the magnitude of the bank capital shock increases the likelihood of bank failures by about 10%, where as increasing the frequency of the shock and holding the size fixed operates by increasing equity issuance.

C.3 Additional results across capital requirements

This section provides an analysis of key financing elasticities and friction measurements between the baseline case of the model with $\chi = 8\%$ and the version with a capital requirement of 26%, which eliminates bank failures. The baseline means correspond to the figures reported in Table 4.

Increasing the capital requirement induces the bank to increase its share of total lending, which implies a greater extent of price competition. As a result, bank loan sizes increase, as does the severity of the financing wedge. Both these values, though, still fall below their non-bank counterparts. The cyclical properties change very little relative to the base case for these variables. Given the lower interest rates the bank charges, demand is somewhat less (more) elastic with respect to price on the extensive (intensive) margin. Monitoring elasticities remain effectively unchanged, as does the bank's choice of monitoring intensity and therefore the cost elasticity of monitoring.

Finally, the marginal valuation term for the bank shifts up on average when the capital requirement is increased, given the increased likelihood of issuing equity. It also becomes more procyclical. This effect, however, happens across all periods, and so it introduces no

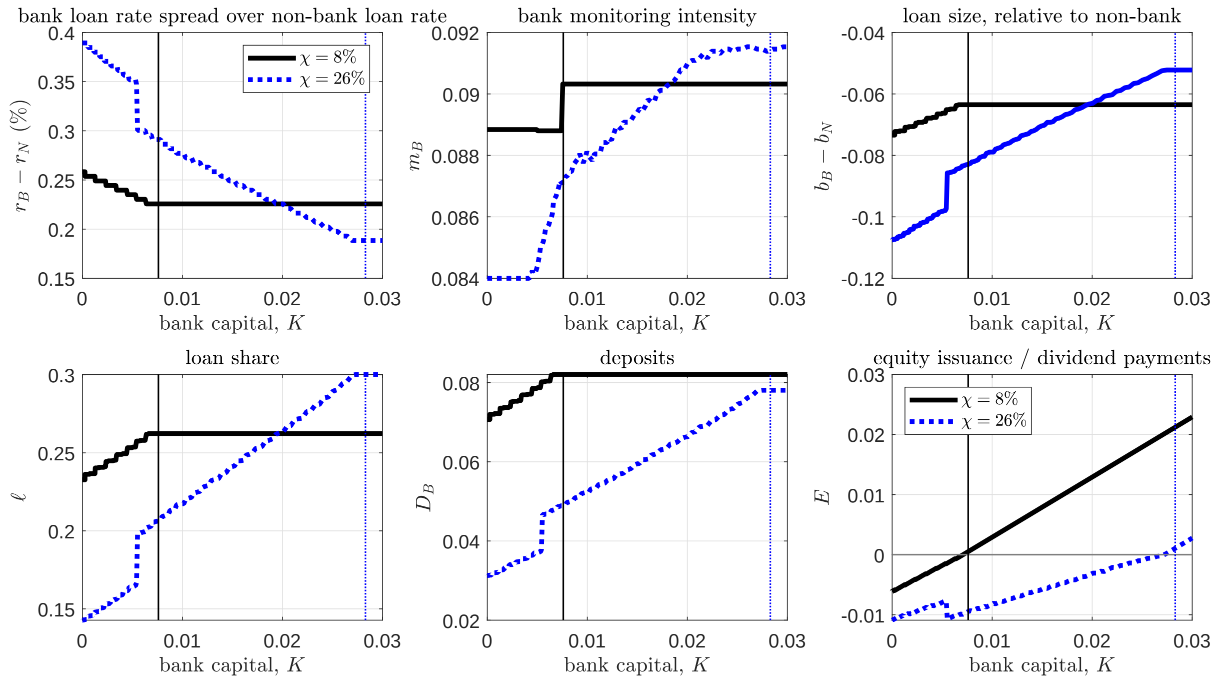

Figure C.1: **Bank policies across capital requirements**

Notes: All figures are constructed under the parameters from Table 1 for the average level of z in the economy, taking the equilibrium q_N as given. In each figure, the vertical line corresponds to the average level of bank capital under the specified capital requirement.

intertemporal distortion into the pricing or monitoring decisions indicated in equations (21) and (22).

Figure C.1 shows how bank policies change by levels of bank capital in the baseline and no failure level of the capital requirement. For a given level of capital such that the bank must issue equity, the bank increases its interest rate spread more under a high capital requirement than under a low capital requirement. This reduces loan demand on both the intensive and extensive margins, enabling the bank to satisfy the capital requirement.

Parameter	**Data**	**Base**	ζ	μ	κ	θ	α	$\overline{c}$	$\overline{z}$	ρ	σ	$\overline{\pi}$	δ_π	$\overline{\lambda}$	δ_λ
net interest margin (%)	3.75	3.89	3.95	3.96	3.90	3.93	5.50	3.90	4.03	3.97	3.91	2.39	3.91	3.89	3.91
avg. C&I C.O. rate (%)	0.78	0.60	0.59	0.61	0.58	0.59	1.17	0.59	0.74	0.61	0.59	0.30	0.60	0.59	0.59
bank share of debt (%)	23.3	23.4	23.1	23.0	23.1	23.2	10.3	23.3	30.6	25.9	23.1	22.9	23.4	23.4	23.0
relative vol, nonbank debt	1.65	1.42	1.38	1.40	1.40	1.38	0.34	1.38	1.02	1.16	1.41	1.40	1.41	1.38	1.42
firm leverage (%)	26.3	27.7	27.7	26.9	26.6	27.3	90.7	27.7	38.1	28.1	27.7	33.3	27.7	27.7	27.7
cyc., bank share of debt	0.29	0.31	0.41	0.35	0.24	0.39	0.67	0.34	0.64	0.74	0.07	0.07	0.09	0.32	0.03
autocorrelation, total debt	0.71	0.72	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.72	0.73	0.73	0.73	0.73	0.73
autocorrelation, GDP	0.88	0.75	0.76	0.76	0.76	0.76	0.82	0.76	0.76	0.75	0.76	0.76	0.76	0.76	0.76
std dev GDP (%)	1.02	1.02	1.01	1.07	0.94	1.04	0.10	1.01	1.03	1.23	1.03	1.08	1.03	1.01	1.01
corp. bond spread (%)	2.80	2.81	2.81	2.83	2.76	2.82	5.27	2.81	3.40	2.82	2.81	1.49	2.81	2.81	2.81
cyclicality, bond spread	-0.63	-0.99	-0.99	-0.98	-0.96	-0.99	-0.84	-0.99	-0.99	-0.53	-0.99	-0.99	-0.99	-0.99	-0.99
bank failure rate (%)	0.79	0.80	0.80	0.80	0.80	0.80	0.00	0.80	0.26	0.52	0.80	0.80	0.80	0.87	0.80
bank eq issue rate (%)	0.07	0.09	0.08	0.08	0.07	0.08	0.01	0.08	0.07	0.07	0.07	0.08	0.07	0.08	0.10

Table C.1: **Sensitivity of target moments to model parameters**

Notes: All moments are denominated in percentage terms. The model period is one quarter, and all interest rates and interest rate spreads are reported in annualized net percentage terms. All business cycle moments are computed using the cyclical component of HP-filtered logs of the data, with the standard smoothing parameter of 1600 for the quarterly frequency. Firm moments come from the QFR; bank moments from the Call Reports; and macro moments from the Flow of Funds.

Capital Requirement	Baseline, 8%			No Failure, 26%		
Moment, x	μ_x	σ_x/σ_y	ρ_{xy}	μ_x	σ_x/σ_y	ρ_{xy}
Panel A: firms' loan demand and loan repayment						
non-bank loan size	0.411	1.740	0.998	0.411	1.733	0.998
non-bank working share	0.995	0.020	-0.994	0.995	0.020	-0.994
non-bank wedge (μ e-2)	0.680	0.015	0.820	0.680	0.015	0.808
bank loan size	0.357	1.726	0.995	0.366	1.732	0.992
bank working share	0.996	0.020	-0.997	0.996	0.020	-0.993
bank wedge (μ e-2)	0.621	0.021	0.919	0.629	0.020	0.880
loan share (count)	0.262	0.320	0.093	0.295	0.783	-0.027
Panel B: firm demand and repayment elasticities, bank borrowing						
IR elas., loan size	-1.308	28.12	0.330	-1.323	38.93	0.206
IR elas., loan share	-6.445	5.763	0.995	-6.186	6.006	0.970
IR elas., repayment	0.008	0.057	0.619	0.008	0.072	0.307
m elas., loan size	0.033	0.301	0.375	0.033	0.261	0.198
m elas.,loan share	0.114	1.247	0.996	0.113	1.214	0.988
m elas.,repayment (μ e-4)	-1.144	0.002	-0.068	-1.143	0.002	0.143
Panel C: bank monitoring and financing						
monitoring intensity	0.089	0.288	0.908	0.090	0.251	0.926
m cost elas. (μ e-4)	3.209	0.002	0.929	3.256	0.002	0.931
marginal val., $\xi'(E) - 1$ (μ e-3)	0.067	0.028	0.079	0.170	0.034	0.272
Γ factor (μ e-3)	0.015	0.056	0.078	0.016	0.067	0.273

Table C.2: **Agency and financial frictions across capital requirements**

Notes: The first column, μ_x denotes the mean of the variable in levels over the simulation. All other moments are HP-filtered on logs of the data using a smoothing parameter of 1600. The second, σ_x/σ_y, is the standard deviation of the variable scaled by the standard deviation of output. The third, ρ_{xy}, is the correlation with output.

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