# Capital Requirements with Non-Bank Finance[*,†]

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**Abstract**

I quantitatively analyze the macroeconomic impacts of raising capital requirements in a model in which heterogeneous firms may choose either intermediated or direct finance. Heterogeneous banks compete with other banks and the bond market, fund loans with insured deposits and costly equity (subject to a minimum capital to asset ratio), and monitor borrowers. I find that tighter capital requirements reduce costly bank failures while having only small effects on key macroeconomic aggregates, and that raising capital requirements above current levels can be welfare-improving. Three main forces give rise to these results. First, even though banks cut loan supply for a given level of net worth under a tighter capital requirement, in equilibrium banks' net worth rises to dampen this effect. Second, intense competition from the non-bank sector disciplines banks' lending responses to tighter regulation. Third, substitution by corporate firms offsets much of the decline in debt financing associated with tighter bank loan supply. As a corollary, almost all of the modest costs associated with tighter capital requirements are concentrated within the bank-dependent non-corporate sector.

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# 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. This paper examines 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 internalize risks and build up capital buffers. While higher capital requirements may decrease risk in the banking sector, they also have the potential to induce banks to decrease credit supply; macroprudential regulators must balance these competing forces.

While commercial banks account for a sizable subset of total lending in the U.S. economy, other lenders also supply significant amounts of credit. What are the aggregate effects of capital requirements when a large share of lending occurs outside the traditional banking sector? The "non-bank" sector has grown both in absolute terms and relative to traditional banking over the last half century, as highlighted for non-financial corporate firms in Figure 1. This sector's size implies that a quantitative model should include it to construct a realistic description of aggregate credit supply. Furthermore, this sector can potentially offset any reduction in commercial bank lending.[2] The degree to which this substitution occurs and its impact on macroeconomic aggregates and risk depends on both equilibrium forces and borrower and lender characteristics.

This paper quantitatively analyzes how non-bank lending alters the transmission of a change in banks' capital requirements to aggregate outcomes. I show that tighter capital requirements make banks safer by promoting larger capital buffers, which are built by retaining earnings and reducing dividends. This additional financial capital dampens the extent to which the stricter regulation leads to more constrained banks in equilibrium. All else equal, banks cut loan supply on the margin, but the impact of this supply shift on borrowers varies by firm type. Among corporate firms who can substitute lenders, competitive discipline from the non-bank sector keeps banks from raising rates. This ability to substitute, together equilibrium declines in bond spreads, actually delivers a modest expansion among these corporate firms. Among bank-dependent non-corporate firms, on the other hand, inability to substitute leads to credit rationing. In the aggregate, the total composition of financing across banks and the bond market is effectively unchanged, while production and investment concentrate more in the corporate sector. The total impacts on output, consumption, and investment are small, on the order of 10 basis points (bps) for a doubling of the capital requirement. Raising the capital requirement to improve bank safety is beneficial: welfare is maximized at 9%, but I find little evidence of large costs to raising it further. Additionally, I show that tighter capital requirements materially improve the economy's resilience to a financial shock.

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

[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%.

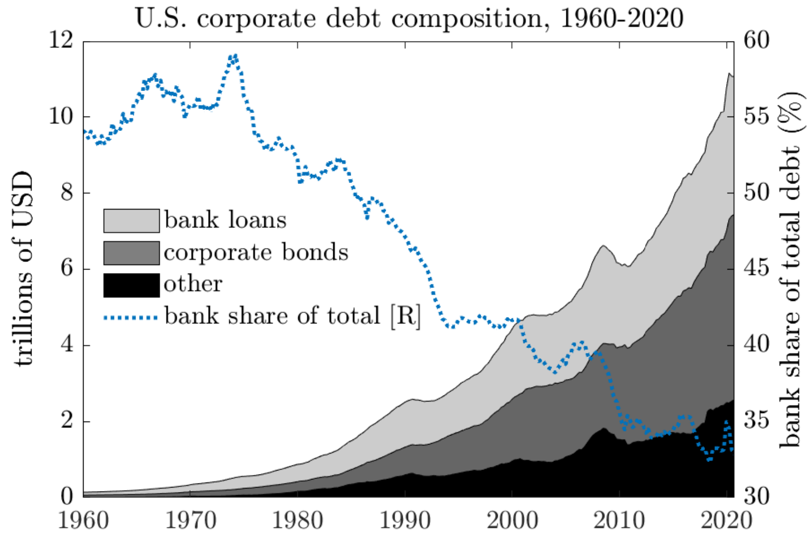


Figure 1: **Growth of alternative debt sources for non-financial business in the U.S.**

**Notes:** Figure is constructed using quarterly data from the Flow of Funds of the Financial Accounts of the United States, 1960Q1 through 2020Q4. Each shaded region represents the total volume of the specified type of debt for non-financial corporate firms. For details on the construction of each category, see Appendix B.

I obtain these results by developing a novel dynamic, stochastic, general equilibrium model in Sections 2 and 3 in which heterogeneous firms borrow via either bank loans or corporate bonds ("non-bank lending"). Firms face idiosyncratic and aggregate productivity shocks, and are subject to an agency friction which yields under-investment. Firms differ ex ante in size and optimal scale, as well as in riskiness and the severity of the agency friction. Critically, firms choose their lenders by comparing the values of the contracts they offer. These values depend on the loan price and how much the lender monitors the borrower to mitigate the agency friction.

Banks are heterogeneous with respect to net worth and have some market power over borrowers as they compete for loan market share with the non-bank sector. There is free entry into banking. I assume that banks have a comparative advantage over the bond market in monitoring, are subject to a financial friction in the form of costly equity issuance, and face a regulatory regime which includes deposit insurance and a capital requirement. Two model features motivate capital requirements. First, banks can use high leverage to shift the downside risk of costly failures to taxpayers since: (i) limited liability protects them from the costs of failure; and (ii) deposit insurance prevents funding costs from responding to failure risk. Second, banks have a comparative advantage in alleviating firms' moral hazard through (costly) monitoring; this has social value, increasing investment and lowering default risk. Banks, however, do not internalize this social benefit, and so capital requirements can help align bank incentives on both fronts. At the same time, though, capital requirements tighten banks' constraints, which may induce them to raise loan rates and cut loan supply.

Aggregates in the model depend on the composition of lending across the financial sectors. As capital requirements increase, then, there are two competing effects. First, banks maintain stronger capital buffers and are less prone to failure, improving welfare. This benefit, however, must be weighed against a substitution effect: the share of non-bank lending may increase to meet loan demand no longer serviced by the banking sector. Since non-bank lenders price loans differently than banks and do not mitigate moral hazard, the net impact of these effects is theoretically ambiguous.

I take the model to the data in Section 4 to resolve this ambiguity. The quantitative model includes "corporate" firms, who may issue corporate bonds and borrow from banks, and "non-corporate" firms, who depend on banks for external financing. This empirically relevant distinction allows for differences in impacts across the business sector. I calibrate the model to match key aggregate and sectoral lending and risk moments by firm type across bank and non-bank sectors. In addition to matching these key targets, I also demonstrate that the model delivers empirically consistent pricing and financing patterns at the micro level: firms in the model who borrow from less capitalized banks are more likely to issue bonds, and the model replicates empirical estimates of the loan-bond spread. I also demonstrate that the model delivers business cycle properties for key macroeconomic aggregates and sectoral financing moments that are in line with the data.

I analyze the long run effects of changing the capital requirement in Section 5. Welfare is maximized at 9%, and the additional costs of further tightening are minor: for example, raising it to 15% keeps aggregate output flat and lowers welfare by just 18 bps in consumption equivalent units relative to the 9% optimum. Though not directly factored into these welfare calculations, I find evidence that tighter capital requirements have the added benefit of improving resilience after a financial shock: after a crisis which wipes out a large share of banks' net worth, the drop in consumption is 25% smaller under a 15% capital requirement than an 8% one. Notably, while top line macroeconomic aggregates are remarkably insensitive to the capital requirement, the composition of financing and production across the business sector are not. For example, raising the capital requirement to 15% causes a 10.9% drop in debt and 1.0% drop in output within the non-corporate sector driven by a 5.8% spike in loan rates, while causing a modest expansion in total debt (+6.5%) and output (+0.5%) within the corporate sector driven better-capitalized banks, declining bond spreads, and the ability to substitute.

In order to understand the mechanisms underlying these results, it is useful to consider sequential margins of transmission: capital requirements first restrict banks' financing options, which induces changes in lending policies, which induces shifts in the composition and amount of firms' external financing and investment. The first of these links in the chain is strong: as capital requirements are raised, bank leverage decreases sharply and the rate of bank failures drops. De-leveraging, though, is not terribly difficult for banks in the model: consistent with the arguments of Admati et al. (2011), I find that they can easily replace deposit financing by retaining earnings over time and cutting (net) dividends on the margin. Consequently, bank net worth rises meaningfully in response to a tighter capital requirement (net worth increases 67% when the requirement is raised to 15%), and so the second link in the chain – from bank financing to bank lending – is only modest. Banks are more constrained for a given level of net worth, but the rightward shift in the distribution of net worth dampens this effect. As a result, loan rates increase only modestly. Changes to loan terms are particularly muted for corporate firms because of competitive discipline imposed by the non-bank sector: banks have only limited market power over these firms to begin with, and a general equilibrium effect which pushes down bond spreads actually increases competitive pressure. In addition, since the value of bank monitoring is generally small, reducing it by tightening banks' constraints has little effect on firms' riskiness in equilibrium. Ultimately, the quantitative evaluation in this paper offers support for proposed increases in 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.

**Related literature** A growing literature, including prominently den Heuvel (2008) and Corbae and D'Erasmo (2021), quantitatively assesses the effects of capital requirements in general equilibrium models. Recent contributions include Nguyen (2014), which studies growth in the presence of bailouts, and Davydiuk (2017), which solves a Ramsey problem for the optimal cyclical capital requirement. 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.

This paper is distinguished by the explicit modeling of firms' choice of lender, which allows for borrower substitution and a richer set of equilibrium responses to changes in capital requirements. The technological foundations in the model 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 Fiore and Uhlig (2011, 2015), apply similar mechanisms to quantitative models of firms' debt choices. 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 the decisions of both firms and banks. In such an environment, regulating the banking sector may induce spillovers across 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.[3] Closely related to my paper is Xiang (2017), which analyzes a quantitative general equilibrium model with complementarity between bank and bond financing arising from ex post renegotiation as in Crouzet (2018). In my framework, lenders affect the use of the underlying technology ex ante, rather than the liquidation decision ex post, and so I focus on substitutability rather than complementarity. In complementary quantitative work, Begenau and Landvoigt (2022) consider a liability-side spillover in the form of banks' production of safe, liquid assets. In their model, asset risk is exogenous, while in mine banks' optimal lending policies affect both the quantity and riskiness of investments. These forces are clearly not exclusive

[3]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. Plantin (2015) studies a similar dynamic.

of each other. Another closely related paper is Elenev et al. (2020), which presents a model similar in structure to mine, but with different sources of firm heterogeneity and no endogenous notion of banks' comparative advantage in lending relative to non-banks. For computational tractability, all the papers in this paragraph make assumptions which ensure that bank policies are linear in bank capital; in contrast, I allow for non-linear policies across the full distribution of bank capital, and show that this matters quantitatively.[4]

# 2 Model Environment

Time is discrete and infinite. There are four types of agents: a unit continuum of firms, a continuum of banks with mass $\overline{\mu}_B$, a representative household, and a government. Both firms and banks are owned by the household. There is a single good used for both consumption and investment. The aggregate state of the economy is $s$. I present a detailed discussion of assumptions in Section 3.6, after laying out the full model.

## 2.1 Firms

**Timing and types** A unit mass of one-period-lived firms are born each period. Firms borrow to build up capital to produce next period. After hiring labor and producing, firms repay creditors and return the profits to the household. They are then replaced by the next cohort. Each firm has a type $j \in \mathcal{J}$ which determines its production technology, endowments, and agency frictions, summarized by a vector of parameters $\Theta_j$ detailed below. The share of type-$j$ firms $\tilde{\mu}_j$ is constant over time.

**Technology** Firms operate a risky, decreasing returns to scale technology that produces output $y$ using capital $k$ and labor $h$: $y = z\varepsilon(k^{\alpha_j} h^{1-\alpha_j})^{\eta_j}$, where $\alpha_j$ is the capital share parameter, $\eta_j$ is the firm's overall returns to scale, $\varepsilon \in [0, \overline{\varepsilon}]$ is idiosyncratic productivity, and $z$ is aggregate TFP. Idiosyncratic productivity is drawn from $G_j(\varepsilon; z)$, which moves with aggregate TFP and has firm-type-specific variance $\sigma^2_{\varepsilon j}(z)$. Total capital combines a firm's endowment, $\overline{k}_j$, and any borrowed funds, $qb$, where $q$ is the discount loan price and $b$ is the face value of the debt: $k = \overline{k}_j + qb$. Operating profits $\pi$ are output less the wage bill $wn$ plus undepreciated capital $(1-\delta)k$.

**Moral hazard and default** After producing, the manager may divert a share $\theta_j \in [0, 1]$ of operating profits $\pi$ away from both shareholders and creditors and retain a share $x(1 - m)$ of these diverted funds for herself, where $x \in [0, 1]$ is an idiosyncratic shock and $m \in [0, 1]$ is the monitoring intensity of a firm's lender. The divertible share $\theta_j$ is common across all firms of a given type, but the share $x \sim F_j(x)$ (with mean $\omega_j$) varies across firms and is drawn after production. Monitoring lowers the returns to diverting by raising the effective cost of doing so. If operating profits net of any diversion and the required debt repayment are negative, the firm defaults. In default, the firms' creditor (of type $i$) recovers a share $1 - \kappa^i_d$ of the un-diverted profits.

[4] Begenau and Landvoigt (2022) find an optimal capital requirement of 16%, slightly above the 10% I find. By contrast, Elenev et al. (2020), find a lower optimum of 6%.

**Matching and borrowing** Each firm is randomly matched with a bank at the beginning of its life. A firm only cares about the contract its bank offers – $(q, m)$, a loan price and monitoring intensity – not its identity or idiosyncratic state. In addition, firms can borrow directly from the household ("non-bank borrowing") under contract $\left(q_j^N(s), \overline{m}\right)$, where $\overline{m} \geq 0$ is a parameter.[5] Given the available contracts, a firm first chooses its lender $i$, weighing two components: the fundamental value of borrowing from lender $i$ and an additive, lender-specific preference shock $\nu^i$ drawn from a type one extreme value distribution with scale parameter $\zeta$. The parameters $(\delta, \kappa_d^i, \zeta)$ are common across firms; the type-specific parameter vector is $\Theta_j = (\overline{k}_j, \alpha_j, \eta_j, \sigma_{\varepsilon j}, \theta_j, \omega_j)$.

## 2.2 Banks

**Competitive structure, financing, and lending** There is a continuum of long-lived, monopolistically competitive banks who are heterogeneous with respect to net worth $n$. Each period, each bank is randomly matched with a mass $1/\overline{\mu}(s)$ of firms of a single type $j$.[6] A bank chooses a loan price $q$ and a monitoring intensity $m$, taking the endogenous loan demand and loan return curves, $L_j^B(q, m; s)$ and $R_j^B(q, m; s, z')$, as given. Monitoring lowers the probability of managerial diversion but increases the per unit cost of lending: the total cost of lending given contract terms $(q, m)$ is $c(m)qL_j^B(q, m; s)$, where $c(m)$ is an increasing, convex function satisfying $c(0) = 1$. Conditional on their firm-type match $j$, banks can finance their operations out of their net worth, by issuing equity $e < 0$ ($e \geq 0$ is a dividend to shareholders), and by issuing risk-free insured deposits $d' \geq 0$, net of any deposit insurance fees at rate $\kappa_d$. Equity issuance is costly, captured by the weakly convex function $\psi(e)$. Banks face a capital requirement: equity (assets net of liabilities) must exceed a fraction $\chi$ of risk-weighted assets.[7]

**Shocks, exit, and entry** At the beginning of the period, incumbent banks realize loan returns and idiosyncratic profit shocks $\phi_p \in [\underline{\phi}_p, \overline{\phi}_p]$, drawn from $H_p(\phi_p; z)$. They then decide whether to exit. If an exiting bank cannot repay its depositors, the government repossesses the banks' assets with fractional loss $\kappa_\varphi \in [0, 1]$. The mass of banks operating is determined by free entry. Specifically, a mass $\overline{\mu}_e$ of potential entrants (with net worth $n_0$ financed by the representative household), draw fixed entry costs $\phi_e$ from a distribution $H_e(\phi_e)$. If the value of entry exceeds the cost, the bank enters and lends in the current period.

## 2.3 Household and the bond market

The representative household consumes $C$, supplies labor $H$ at the competitive wage $w(s)$, lends to banks via insured deposits $D'$ at the competitive discount price $\overline{q}(s)$, lends directly to firms

[5]That is, the household does not choose monitoring intensity. This assumption is not critical, as discussed in 3.6.

[6]Think of a "double continuum:" each point (bank) along the length-$\overline{\mu}_B$ interval is matched with a unit line (firms) from interval from a "unit square."

[7]Risk-weighted assets here are $qL_B$. Consistent with Basel II, I assume that all loans to firms in the model have a risk-weight of 1. Banks in the model can in principle choose to hold riskless securities with a risk weight of zero by choosing $d' < 0$, but this is never optimal.

via corporate bonds $\{L_j^N\}_{j \in \mathcal{J}}$, buys bank shares $\{\sigma'(n)\}_{n \in \mathcal{N}}$ at ex-dividend prices $\{\rho(n;s)\}_{n \in \mathcal{N}}$, and collects firms' total profits $\Pi(s)$. The household lends competitively, taking as given the loan price $q_j^N(s)$ and the state-by-state return $R_j^N(s, z')$. The household has standard, additively separable preferences $U(C, H)$ over consumption and leisure and discounts the future at rate $\beta$. The household's stochastic discount factor between aggregate states $s$ and $s'$ is $M(s, s')$.

The household's direct lending comprises the bond market, which is the only non-bank alternative to bank lending in the model. This is, of course, a simplification: many financial institutions that are not traditional commercial banks lend to firms. As documented in Figure 1, though, corporate bonds comprise a large share of total business debt held outside the traditional banking sector. For this reason, as well as for tractability, I specify the non-bank sector in this way.

### 2.4 Government

The government runs a balanced budget each period and so covers spending $\overline{G}$, deposit shortfalls of failed banks, and any transfers $T(s)$ (or lump-sum taxes if $T < 0$) from: (i) labor income taxes (at rate $\tau_h$); (ii) taxes on firms' profits (at rate $\tau_\pi$); (iii) taxes on interest income (at rate $\tau_d$); (iv) deposit insurance fees (at rate $\kappa_d$ per unit of deposits); and (v) recoveries from failed banks.

### 2.5 Timing

The aggregate state of the economy relevant for decision-making is aggregate TFP, $z$, the distribution of banks over net worth $n$, $\mu(n)$,[8] and the distribution of firms over capital $k$, debt $b$, types $j$, and lenders $i$, $\tilde{\mu}_j^i(k, b)$. The timing within a period is as follows:

1. Given their idiosyncratic productivity shocks, firms hire labor and produce. Given operating profits and their diversion shock, managers decide whether to divert. **(firm stage 3)**

2. Given the remaining un-diverted funds, firms either pay back their lenders in full or (partially) default. Profits net of repayments are returned to the household, and firms exit.

3. Given realized loan returns and return shocks, incumbent banks make exit decisions, and potential entrant banks make entry decisions.[9] **(bank stage 1)**

4. Given collections from failed banks and required deposit shortfalls, the government levies taxes, and the household consumes.

5. New firms enter and are matched with banks.

6. Given their firm-type match, banks choose their loan contract and financing. **(bank stage 2)**

7. Given their bank match, firms choose their lender. **(firm stage 1)**

8. Given their choice of lender, firms choose how much to borrow. **(firm stage 2)**

[8] Note that this distribution includes the total mass of operating banks, $\overline{\mu}(s) = \int_{\mathcal{N}} \mu(n)$.

[9] It is at this point that the distribution of banks updates to $\mu(n)$ from $\mu_{-1}(n)$.

The timing above implies that it is most useful to begin analysis of the model from step 5, at which point the household knows its net worth for the period. I follow this convention in what follows.

# 3 Equilibrium

## 3.1 Firms' problems

**Stage 3: production, diversion, and default** Operating profits for a type $j$ firm with capital $k$ given idiosyncratic productivity $\varepsilon$ and aggregate state $s$ are

$$\pi_j(k,\varepsilon;s) = \max_h z(s)\varepsilon(k^{\alpha_j}h^{1-\alpha_j})^{\eta_j} - w(s)h + (1-\delta)k \tag{1}$$

with associated optimal labor demand $h_j(k,\varepsilon;s)$ and output $y_j(k,\varepsilon;s)$.[10] Note that undepreciated capital appears in the definition of operating profits; despite the fact that firms are one-period-lived and therefore have no strict continuation value, they invest similarly to longer-lived firms since they internalize the value of their remaining capital in addition to their revenues.

Given operating profits $\pi$, debt $b$, and the realization of the diversion rate $x$, managers must decide whether or not to divert operating profits away from shareholders and creditors to themselves. The manager values the proceeds from un-diverted funds exactly as shareholders do. Therefore, the manager chooses to divert funds if and only if

$$\underbrace{\max\{\pi_j - b, 0\}}_{\text{payoff without diversion}} \geq \underbrace{\max\{(1-\theta_j)\pi_j - b, 0\} + x(1-m)\theta_j\pi_j}_{\text{payoff with diversion}}$$

which occurs when

$$x \geq \overline{x}_j(\pi_j, b; m) = \begin{cases} 0 & \text{if } \frac{b}{\pi_j} > 1 \\ \frac{1-\frac{b}{\pi_j}}{(1-m)\theta_j} & \text{if } 1-\theta_j < \frac{b}{\pi_j} < 1 \\ \frac{1}{1-m} & \text{if } \frac{b}{\pi_j} < 1-\theta_j \end{cases} \tag{2}$$

When $b/\pi_j > 1$ (which occurs when $\varepsilon < \underline{\varepsilon}^D(\pi, b)$), the debt burden exceeds operating profits and default is unavoidable. Shareholders receive nothing, and so the manager must divert to get any payoff; thus she diverts for any $x \geq 0$. When $b/\pi_j < 1-\theta_j$ (i.e. $\varepsilon > \underline{\varepsilon}^{ND}$), profits are so high that default will not occur even if the manager diverts. In the middle region ($b/\pi_j \in [1-\theta_j, 1]$ or $\varepsilon \in [\underline{\varepsilon}^D, \underline{\varepsilon}^{ND}]$), only diversion will lead to default. Here, diversion is less likely when: (i) the degree of moral hazard $\theta_j$ is lower; (ii) the profits relative to debt repayments $b/\pi_j$ are lower; and (iii) monitoring intensity $m$ is higher. Since default in this middle region $[\underline{\varepsilon}^D, \underline{\varepsilon}^{ND}]$ comes only from diversion, this is termed the "moral hazard" region.

Figure 2(a) summarizes these regions in the $(\varepsilon, x)$-plane. An un-monitored firm (solid line) has the largest moral hazard region, and a lower diversion threshold $\overline{x}$ at every level of productivity $\varepsilon$. More monitoring (dashed line) shifts $\overline{x}$ in the moral hazard region, shrinking both the size of and

[10] See Appendix A.1.1 for closed-form expressions for these objects.

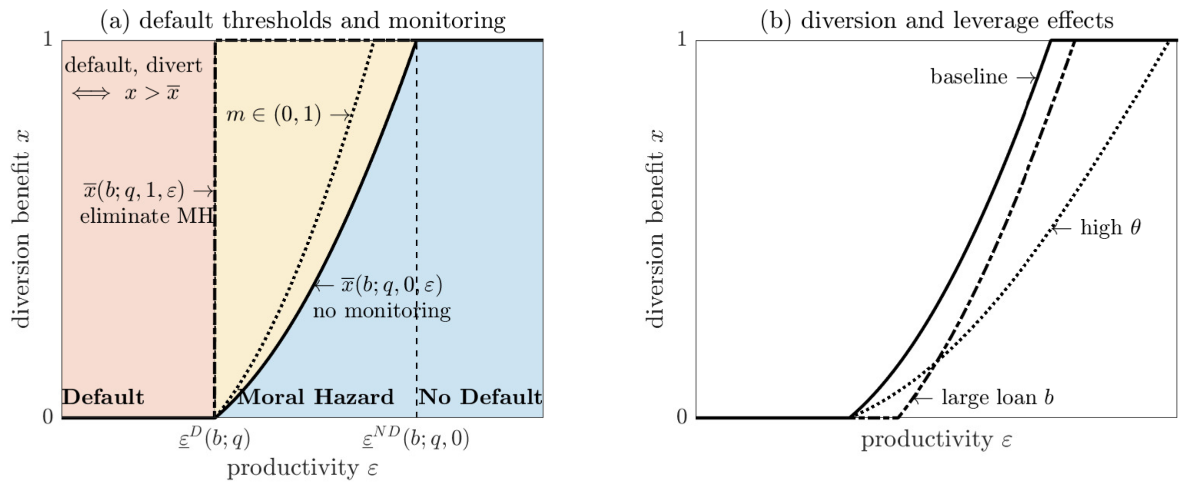


Figure 2: **Default and diversion in firms' stage 3**

**Notes:** Panel (a) plots the 3 regions in the interval $[0, \overline{\varepsilon}]$ defined by the default and diversion cutoffs: (i) in the default region $[0, \underline{\varepsilon}_D]$, $\overline{x} = 0$ and the manager (firm) always diverts (defaults); (ii) in the moral hazard region $[\underline{\varepsilon}_D, \underline{\varepsilon}_{ND}]$, the manager (firm) diverts (defaults) only if $x \geq \overline{x}$; and (iii) in the region $[\underline{\varepsilon}_{ND}, \overline{\varepsilon}]$ the manager (firm) never diverts (defaults). Panel (b) shows the effect of raising the moral hazard parameter $\theta_j$ and the loan size $b$ on these regions.

the likelihood of default in the moral hazard region.[11] Figure 2(b) shows how a firm's type (via $\theta_j$) and leverage choice (via loan size $b$) shape default. Increasing $\theta$ does not change $\underline{\varepsilon}^D$ since it does not affect net profits directly, but does raise $\underline{\varepsilon}_{ND}$ by making diversion more attractive. Increasing $b$ raises both $\underline{\varepsilon}^D$ and $\underline{\varepsilon}^{ND}$ by decreasing net profits.

Given the fact that the firm's type $j$, the loan price $q$, and the loan size $b$ pin down the firm's level of capital $k = \overline{k}_j + qb$ at the time of production, for the rest of the analysis I suppress the argument $k$ in the objects presented to this point. For example, total operating profits $\pi_j(k, \varepsilon; j, s)$ will be written $\pi_j(b, \varepsilon; q, s)$, and likewise for other objects.

**Stage 2: loan size choice** Fixing a lender and thus fixing $(q, m)$, the firm solves

$$v_j(q, m; s) = \max_{b \geq 0} \mathbb{E}_{z'|s} \left[ M\left(s, \Gamma(s, z')\right) \Pi_j\left(b; q, m, \Gamma(s, z')\right) \right] \tag{3}$$

where $M(\cdot)$ is the household SDF, $\Gamma(\cdot)$ is the law of motion for the $s$, and $\Pi(\cdot)$ is expected net profits in state $s'$ from borrowing $b$ at terms $(q, m)$, controlling for managerial behavior:[12]

$$\Pi_j\left(b; q, m, s\right) = \int_0^{\overline{\varepsilon}} F_j(\overline{x}_j(b, \varepsilon; q, m, s))[\pi_j(b, \varepsilon; q, s) - b]^+ \mathrm{d}G_j(\varepsilon; z(s)) \tag{4}$$

[11] The area between the $\overline{x}(b; q, m, \varepsilon)$ and $\overline{x}(b; q, 0, \varepsilon)$ curves measures the reduction in default probability associated with monitoring. Similar to Xiang (2017), this implies that banks can help firms avoid financial distress, but from ex ante deterrence rather than ex post restructuring.

[12] Having one-period-lived firms value undepreciated capital avoids an artificial distortion between their investment decisions and those of long-lived firms. The assumption that default and diversion is governed by operating profits only is standard in the literature; see, for example, Elenev et al. (2020).

The firm's optimal loan size, $b_j^*(q,m;s)$, equates the marginal increase in expected operating profits to the marginal increase in debt repayments. Moral hazard implies that this tradeoff must account for the fact that that increased indebtedness raises the probability of diversion in the moral hazard region ($\frac{\partial \overline{x}}{\partial b} < 0$). This agency cost leads to rationing of borrowing and investment.[13]

**Stage 1: lender choice** Each firm chooses its lender to maximize the sum of the fundamental value associated with choosing lender $i$, $v(q_i, m_i; j, s)$ from (3), as well as an idiosyncratic preference shock $\nu_i$. Conditional on being matched with a bank offering contract $(q,m)$, a firm solves

$$V_j^F(q,m,\nu;s) = \max_{\iota \in \{0,1\}} \iota \left(v_j(q,m;s) + \nu^B\right) + (1-\iota)\left(v_j^N(s) + \nu^N\right) \tag{5}$$

where $v_j^N(s) \equiv v_j^N\left(q_j^N(s), \overline{m}; s\right)$. Since $\nu$ is distributed type one extreme value with scale parameter $\zeta$, the share of firms choosing bank lending is

$$\ell_j^B(q,m;s) \equiv \mathbb{P}_\nu\left(\iota_j^*(q,m,\nu;s) = 1\right) = \left[1 + \exp\left\{\frac{v_j^N(s) - v_j(q,m;s)}{\zeta}\right\}\right]^{-1} \tag{6}$$

with a complementary fraction $\ell^N = 1 - \ell^B$ choosing non-bank lending. Fixing $\zeta$, the mass of firms choosing bank lending declines if the non-bank contract becomes more attractive ($v_N$ increases) or if the bank contract becomes less attractive ($v(q,m)$ decreases). Fixing the contract values, the higher-value contract always attracts a higher share of firms, and this share is increasing in $\zeta$.[14]

In the quantitative analyses, we assume that one firm type is completely bank-dependent and cannot issue bonds. For these firms, $\ell^B = 1$ and $\ell^N = 0$. There is only an intensive margin of bank loan demand for these firms, while other firms also have the extensive margin.

**Loan demand and loan return curves** Banks and the household must be able to map out how different contracts and shock realizations affect loan demand and returns. Denote by $b_j^N(s)$ the optimal loan size conditional on choosing non-bank lending. Conditional on the firm's type and its match with a bank offering $(q,m)$, the demand curve for loans from lender $i$ is:

$$L_j^i(q,m;s) = \begin{cases} \overline{\mu}_B^{-1}(s)\ell_j^B(q,m;s)\, b_j^*(q,m;s) & \text{if } i = B \\ \overline{\mu}_B^{-1}(s)\ell_j^N(q,m;s)\, b_j^N(s) & \text{if } i = N \end{cases} \tag{7}$$

which combines: (i) the mass of firms matched, $\overline{\mu}_B^{-1}$; (ii) the share of those firms choosing lender $i$; and (iii) the optimal loan size conditional on lender $i$.

When the firm does not default, lenders are repaid in full. When the firm defaults, the lender

[13] See Appendix A.1.1 for details. Replacing $b$ with $b^*$ in the expressions for $\underline{\varepsilon}^D$ and $\underline{\varepsilon}^{ND}$ yields the implied thresholds for each possible future aggregate state $\underline{\varepsilon}_j^{D*}(q,m;s,z')$ and $\underline{\varepsilon}_j^{ND*}(q,m;s,z')$, where $s'$ is replaced by $\Gamma(s,z')$ and arguments are collapsed. Applying the law of large numbers and integrating over $\varepsilon$ and $x$ delivers average profits $\pi^*$, output $y^*$, labor demand $h^*$, default rates $\xi^*$, and other firm-level objects in a similar way.

[14] As $\zeta$ shrinks, large realizations of $|\nu_N - \nu_B|$ that "sway" firms from the highest value contract become less likely.

claims the un-diverted output. Therefore, the lender's per-unit return in state $z'$ is

$$R_j^i\left(q,m;s,z'\right) = \int_0^{\overline{\varepsilon}} \Bigg\{ \underbrace{F_j(\overline{x}_j^*(q,m;s,z',\varepsilon))}_{\text{full repayments}} + \underbrace{\left(1-F_j(\overline{x}_j^*(q,m;s,z',\varepsilon))\right)(1-\kappa_d^i)(1-\theta_j)\frac{\pi_j^*(q,m;s,z',\varepsilon)}{b_j^*(q,m;s)}}_{\text{partial repayments in default}} \Bigg\} \mathrm{d}G_j(\varepsilon;z') \tag{8}$$

Since $q_j^N(s)$ is competitively determined, we can suppress contract terms and write $R_j^N(s,z')$.[15]

### 3.2 Banks' problem

**Stage 2: lending and financing** A bank with net worth $n$ matched with type $j$ firms in aggregate state $s$ solves

$$V_j^B(n;s) = \max_{e,q,m,d',n'} e + \mathbb{E}_{\phi_p,z'|s}\left[M(s,s')\overline{V}^B\left(n';s'\right)\right] \tag{9}$$

$$\text{subject to:} \quad \psi(e) + c(m)qL_j^B(q,m;s) \leq n + \left(\overline{q}(s) - \kappa_d \mathbf{1}[d'>0]\right)d' \tag{10}$$

$$n' = R_j^B(z',q,m;s)L_j^B(q,m;s) - d' + \phi_p \text{ for all } z',\phi_p \tag{11}$$

$$\chi q L_j^B(q,m;s) \leq qL_j^B(q,m;s) - \overline{q}(s)d' \tag{12}$$

and the aggregate law of motion $s' = \Gamma(s,z')$. The functions $L^B(\cdot)$ and $R^B(\cdot)$ are given by (7) and (8). The weighting of $\overline{V}^B$ from (13) by the household SDF in the objective function (9) reflects household ownership. The flow budget constraint (10) states that dividends ($e \geq 0$) and loans (issued at total cost $c(m)qL^B$) must be financed from net worth, deposits net of insurance fees ($(\overline{q}-\tau_d)d' \geq 0$), and equity issuance net of issuance costs ($\psi(e) < 0$). Constraint (11) defines net worth tomorrow as the sum of loan returns $R^B(z')L^B$ and return shocks $\phi_p$, net of deposit repayments. Constraint (12) is the capital requirement: the left-hand side is total total risk-weighted assets, and the right-hand side is total equity (assets net of liabilities).

Let $q_j^B(n;s)$ and $m_j^B(n;s)$ denote a bank's optimal loan contract terms, and let $d_j'(n;s)$, and $e_j(n;s)$ denote its optimal financing policies. Denote the face value of loans and return implied by the bank's optimal contract by $\mathcal{L}_j^B(n;s)$ and $\mathcal{R}_j^B(n;s,z')$, respectively. Finally, denote the bank's net worth at the start of next period after the realizations of $\phi$ and $z'$ shocks conditional on optimal pricing and financing policies as $n_j'^*(n;s,z',\phi_p)$.

**Stage 1: exit and entry** At the beginning of the period, a bank with net worth $n$ must decide whether or not to exit. This decision is made before the bank learns its firm-type match:

$$\overline{V}^B(n;s) = \max_{x\in\{0,1\}} (1-x) \sum_{j\in\mathcal{J}} \tilde{\mu}_j V_j^B(n;s) \tag{13}$$

[15] The quantity of non-bank loans depends on bank-firm matches, but the return does not.

If the continuation value from choosing not to exit ($x = 0$), which accounts for the random matching of a bank with a set of firms and the stage 1 value function $V_B(\cdot)$ defined below, is positive, the bank continues. Otherwise, the bank exits ($x = 1$), paying nothing to its shareholders. Let $x^B(n; s)$ be the solution to (13). As discussed in Section A.2.1 below, this will determine the mass of banks exiting in a given state, $\omega_0(s)$. A potential bank will enter as long as the value of entry, $\overline{V}^B(n_0; s)$, exceeds the entry cost $\phi_e$. Therefore, the mass of entrants is

$$\omega_1(s) = \overline{\mu}_e \times \mathbb{P}_{\phi_e}\left(\overline{V}^B(n_0; s) \geq \phi_e\right) = \overline{\mu}_e H_e\left(\overline{V}^B(n_0; s)\right) \tag{14}$$

The solution $V^B(\cdot)$ to the stage 2 problem (9) – (12) is increasing in net worth. This implies that the solution to the stage 1 problem (13) can be described by a threshold rule: there exists $\underline{n}(s)$ such that for all $n < \underline{n}(s)$, $x^B(n; s) = 1$. Given initial state $s$ and a realization of $z'$, a bank exits if and only if:

$$\phi_p < \varphi_j(n; s, z') \equiv \underline{n}\left(\Gamma(s, z')\right) + \underbrace{d'_j(n; s) - \mathcal{R}^B_j(n; s, z')\mathcal{L}^B_j(n; s)}_{=\phi_p - n'^*_j(n; s, z', \phi_p)} \tag{15}$$

Therefore the total number of bank failures next period, conditional on $z'$, is

$$\omega_0(s, z') = \sum_{j \in \mathcal{J}} \tilde{\mu}_j \int_{\mathcal{N}} H_p\left(\varphi_j\left(n; s, z'\right); z'\right) \mathrm{d}\mu(n) \tag{16}$$

### 3.3 Household: determining equilibrium prices

The full statement of the household problem may be found in Appendix 3.3. Given the household's stochastic discount factor

$$M(s, s') = \beta \frac{U_C(C(s'), H(s'))}{U_C(C(s), H(s))} \tag{17}$$

the household's problem implies the following set of standard optimality conditions for deposits, labor supply, direct loan supply, and bank shareholdings, respectively:

$$\overline{q}(s) + \tau_d\left(\frac{1}{\overline{q}(s)} - 1\right) = \mathbb{E}_{z'}\left[M\left(s, \Gamma(s, z')\right)\right] \tag{18}$$

$$w(s) = -\frac{1}{1 - \tau_h} \frac{U_H(C(s), H(s))}{U_C(C(s), H(s))} \tag{19}$$

$$q^N_j(s) = \frac{1}{c(\overline{m})}\left(\mathbb{E}_{z'}\left[M\left(s, \Gamma(s, z')\right) R^N_j(s, z')\right] - \kappa_L\right) \tag{20}$$

$$\rho_j(n; s) = \mathbb{E}_z\left[M\left(s, \Gamma(s, z')\right) \overline{V}^B\left(n'; \Gamma(s, z')\right)\right] \tag{21}$$

where $\rho$ is the ex-dividend bank share price function. Equation (18) determines deposit supply (and therefore the risk-free rate $\overline{r}(s) = \overline{q}^{-1}(s) - 1$) given the interest income tax $\tau_d$ and the household SDF. Equation (19) determines labor supply by equating the after tax wage with the household's marginal rate of substitution of leisure for consumption. Equation (20) determines loan supply similarly to deposit supply, but adjusting for the relevant costs and returns of non-bank lending.

Finally, equation (21) confirms $\rho$ as the ex-dividend share price for banks.

### 3.4 Government

**Bank failure costs** An exiting bank pays off as much of its total deposits as it can from its loan returns and $\phi$. If these are not enough to cover its deposits, the government takes control, losing a fraction $\kappa_\varphi$ of the bank's profits in the process. The required deposit insurance payments associated with bank failures next period state by state, then, is

$$X(s,z') = \kappa_\varphi \sum_{j\in\mathcal{J}} \tilde{\mu}_j \int_{\mathcal{N}} \left( \int_{\underline{\phi}_p}^{\varphi_j(n;s,z')} \left[d_j'(n;s) - \phi_p - \mathcal{R}_j^B(n;s,z')\mathcal{L}_j^B(n;s)\right]^+ \mathrm{d}H_p(\phi_p;z') \right) \mathrm{d}\mu(n) \tag{22}$$

**Budget constraint** The government must finance expenditures $\overline{G}$ and any deposit insurance payments associated with failed banks out of labor income and profit taxes as well as deposit insurance fees. I assume that the government runs a balanced budget each period so that

$$\overline{G} + X(s) + T(s) \leq \tau_h w(s) H(s) + \left(\kappa_d + \tau_d \left(\frac{1}{\overline{q}(s)} - 1\right)\right) D(s) + \tau_\pi \Pi(s) \tag{23}$$

where $D(s) = \sum_j \tilde{\mu}_j \int_{\mathcal{N}} \max\{d_j'(n;s), 0\}\mathrm{d}\mu(n)$ is total bank deposit issuance.

### 3.5 Equilibrium definition

A **recursive competitive equilibrium** consists of: (i) firm value functions $V_j^F$ and $v_j$ with associated optimal policies $\{\pi_j, h_j, y_j, b_j, \ell_j^i\}$; (ii) bank value functions $V_j^B$ and $\overline{V}^B$ with associated optimal policies $\{x^B, q_j^B, m_j^B, d_j', e_j\}$; (iii) a household value function $V^H$ with associated optimal policies $\{C, H, D', \{L_j^N\}, \{\sigma(n)\}\}$; (iv) a transfer function $T$; (v) a price vector $\{\overline{q}, w, \rho, \{q_j^N\}\}$; (vi) a $z$-specific return vector $\{R_j^N, R_j^B, \Pi\}$; and (vii) distributions of firms and banks $\tilde{\mu}$ and $\mu$, together with a law of motion $\Gamma$ such that

1. **Firms optimize:** Firm-specific output $y_j$, labor demand $h^*$, and operating profits $\pi^*$ solve (1) given the optimal loan size $b^*$ conditional on lender choice, which solves (3). Conditional on a bank match, $V_F$ solves (5) with $\ell_B^*$ given by (6) and $\ell_N^* = 1 - \ell_B^*$.

2. **Banks optimize:** $V_j^B$ and $\{q_j^B, m_j^B, d_j', e_j\}$ solve (9) - (12), $\overline{V}^B$ and $x^B$ solve (13), and the mass of entrants is determined by (14).

3. **Household optimizes:** $V_H$ and $\{C, H, D', \{L_j^N\}, \{\sigma(n)\}\}$ solve (A.32) - (A.33).

4. **Government:** (23) is satisfied, with deposit insurance costs given by (22).

5. **Distributions:** the law of motion $\Gamma$ is consistent with the evolution of the firm and bank distributions (see Appendix A.3).

6. **Returns are consistent:** The aggregate-state-specific return vectors $R_j^i$ satisfy (8). Total firm dividends $\Pi^*$ are given by (A.13).

7. **Markets clear:** Non-bank loan, bank share, deposit, labor and goods markets all clear. That is, conditions (18) – (21) are satisfied.[16]

### 3.6 Discussion of assumptions

**Two-sided moral hazard** Capital requirements interact with two moral hazard frictions in the model. The first is managerial diversion, which induces a wedge into firms' investment decisions and lowers returns ex ante, leading firms to self-ration investment and production. Banks' monitoring mitigates this distortion by lowering managers' private benefits from diversion. My specification adapts Holmstrom and Tirole (1997) with a key modification: investments can have positive net present value even if the manager shirks. Thus bank monitoring influences both the quantity and riskiness of investment along the equilibrium path, rather than only the quantity.

The other moral hazard is standard bank risk-shifting: limited liability and deposit insurance protect bank shareholders against loan losses. In addition to promoting high leverage, this keeps banks from internalizing the full benefits from monitoring: since monitoring reduces diversion and default most in bad states of the world, cutting it has a disproportionate effect on bank loan performance in downturns. In this way, risk-shifting lowers the amount of risk mitigation performed by banks in the model. On the other hand, however, financially constrained banks may choose to save on current period loan financing costs by cutting monitoring.[17] The total effect of a tighter capital requirement on banks' monitoring, then, is ambiguous a priori.

**Firm heterogeneity** There is considerable ex-post firm heterogeneity in the model with respect to capital, debt, productivity, lender choice, and managerial behavior. This allows for richness in production and default behavior that characterizes the business sector in the real world. The timing of idiosyncratic shocks which yields this structure keeps the analysis of the firm problem tractable, which is essential since lenders must know the full loan demand and loan return functions for each type of firm in each state of the world. This ex-post heterogeneity arises despite there being only one source of ex-ante heterogeneity: firm type $j$, which determines the parameter vector $\Theta_j$ and allows firm types to differ with respect to capital, size, risk, and the severity of agency frictions. These differences allow for meaningful and empirically plausible variation in sorting between lenders based on "fundamentals," in addition to the idiosyncratic taste shocks $\nu$.

**Firms' life span** The assumption that firms are short-lived simplifies the model by reducing the state space. Long-lived firms operating a decreasing returns technology subject to idiosyncratic

[16]Bank loan market clearing is guaranteed given banks' market power. For all $j$, the supply of non-bank loans $L_j^N(s)$ matches the demand in equation (A.15). Optimal shareholdings $\mathrm{d}\sigma'(n) = \mathrm{d}\mu(n)$ for all $n$. Optimal household investment in deposits $D'(s)$ equals total supply. Optimal labor supply $H(s)$ equals total labor demand implied by firms' optimal decisions. The goods market clears by Walras' Law.

[17]Cutting monitoring both reduces the unit cost of a given pool of loans and reduces total loan demand.

shocks would lead to a non-degenerate distribution of firm capital that wouldn't evolve as a function of the bank distribution and would be part of the aggregate state vector. In addition, lenders would have to index contracts on firm type and capital, and so the number of control variables in the bank problem would increase as well.[18] Moreover, I ensure that firms' investments reflect the continuation value of their capital via the undepreciated capital term in (4).

**Lender-specific preference shocks** The $\nu$ shocks in the lender choice problem (5) create a non-degenerate demand schedule for each lender while maintaining ex ante identical firms within each type, keeping the model tractable. Without these shocks, firms would either borrow from a single lender or be indifferent between lenders; the former would lead to a degenerate debt composition, the latter an indeterminate one. These shocks, then, allow the model to match the generically interior debt compositions we observe among firms with access to bond markets.[19] They also smooth out substitution patterns between types of lenders in response to regulatory changes.

**Bank competition** Banks compete in two ways in the model. First, conditional on being matched with a set of borrowers, a bank competes only with direct lending: its customers may issue bonds, but not seek other banks. This provides banks a degree of market power since they can "best respond" given non-bank terms. This is consistent with a long literature documenting that banks have some degree of market power, reflected in high and stable net interest margins.[20] Banks exercise this market power based on firm characteristics, ultimately determining helps determine both the bank share of debt and banks' profitability. Second, banks compete with each other via entry.[21] If charter values are large, more banks enter, diluting the loan market share a given bank will command. This limits the extent to which banks can avoid constraints by simply charging high markups. This structure also helps determine the absolute size of banks in the model, since banks cannot increase the share of with which firms they are matched as they grow.

**Non-bank institutions** This paper studies how an outside option for borrowers alters the equilibrium assessment of changes to bank capital requirements. The simplest and most empirically relevant (see Figure 1) approach to creating this non-bank outside option is a competitive corporate bond market.[22] An alternative would involve other levered financial institutions with different regulatory schemes (i.e. no deposit insurance or capital requirement). While important, this would bring

[18]A related model, Elenev et al. (2020), circumvents this issue by making firms' decisions linear in net worth via a binding constraint. Since households in my model own the firms and both finance firms' initial capital and receive both their profits and undepreciated capital, these settings ultimately behave quite similarly, with the caveat that the initial capitalization of the firm sector in my model is exogenous.

[19]In the empirical 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)).

[20]See, for example, Berger and Hannan (1998) and Guevara et al. (2005). Furthermore, this is consistent with the quantitative model in Corbae and D'Erasmo (2021), as well as the theory of Boyd and Nicolo (2005).

[21]This is in the spirit of Hopenhayn (1992), adopted widely throughout the heterogeneous firm and bank literature, for example in Corbae and D'Erasmo (2021).

[22]The assumption of perfect competition is further motivated by the low average spreads above fundamental default risk on corporate bonds across risk subgroups, as documented in Schwert (2018).

a large set of issues requiring modeling assumptions and quantitative discipline which would strain tractability in the current setting.[23] Furthermore, I assume that the household does not choose monitoring. This assumption is fairly nonrestrictive: one can think of $\theta_j$ and $F(x)$ as determining the extent of moral hazard *above and beyond* that which can be mitigated in the bond market, and the cost function $c(m)$ as the cost of this additional mitigation.[24]

**Matching of firms and banks** The model includes random matching of banks with a mass of firms of a *single* type in each period. This technology allows the model to have multiple firm types without requiring individual banks to solve for a full *portfolio* of loan contracts, which would be intractable. As discussed above, this also gives banks a degree of market power in the lending stage. An alternative approach which weakens this effect is competitive or directed search. Here, banks would post contracts and borrowers would search based on the value of the contracts offered and the tightness in each sub-market. Given the two-sided heterogeneity in this model, however, this would add significant computational complexity.

# 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 across firm sectors, default risk across lender types, bank capital structure, and bank failure risk. This section describes how the quantitative model replicates these features of the data, making it a suitable laboratory for understanding the impacts of capital requirements. Section 4.1 begins by describing the implementation of the set of firm types $\mathcal{J}$. Section 4.2 describes how the key parameters of the model are chosen: a subset are chosen independently of the model solution (4.2.1), while the rest are chosen to match important moments (4.2.2). Section 4.3 explores the role of key frictions through parameter variations, and Section 4.4 considers how the model performs with respect to relevant empirical moments not explicitly targeted in the calibration.

## 4.1 Specification of firm types in the quantitative model

The quantitative model has three types of firms: A-rated corporates ($j = a$), B-rated corporates ($b$), and non-corporates ($n$). I assume that non-corporate firms are completely bank-dependent; that is, the share of firms of this type choosing bank lending is always one. This reflects the empirical regularity that many firms (particularly smaller, younger firms) do not have access to bond markets. Among corporate firms, A-rated firms correspond to those who can issue bonds easily, while B-rated firms may face more frictions in this regard. This setup trades off parsimony with richness:

[23] Begenau and Landvoigt (2022) take this approach in a somewhat different model than the one presented here. A natural extension to the present model would be to have each firm matched with both a bank and a "shadow bank," and make a 3-pronged loan sourcing choice. This would require not only an additional dynamic problem – that of the shadow bank – but also the strategic game between banks and shadow banks.

[24] Indeed, Chava et al. (2010) find evidence that managerial entrenchment and fraud influence the use of bond covenants using a large sample of corporate bonds from 1993-2007.

firms in the model vary in their degree of bank dependence, and even firms who are not explicitly bank-dependent can in principle differ in their ability to substitute across lenders. Firm types may also differ with respect to initial size and optimal scale. I place minimal ex ante restrictions on the relationships across $j$ of the parameter vector $\Theta_j$, instead allowing them to be informed by salient moments of the data as described below.

## 4.2 Calibration

### 4.2.1 Externally assigned parameters

**Household** Table 1 presents the model parameters which I assign directly. Panel A describes the subset related to the representative household. The model period is one quarter. I set $\beta = 0.998$ to target an average annualized risk-free rate of 1%.[25] The utility function of the representative household is quasilinear in labor: $U(C, H) = \frac{C^{1-\gamma}}{1-\gamma} - AH$, with a coefficient of relative risk aversion $\gamma = 2$ and a labor disutility coefficient $A = 2.5$, in the range of standard values used in the literature.[26] To capture potential frictions associated with direct lending, I follow Elenev et al. (2020) and assume there is a household loan issuance cost $\kappa_L$ equivalent to 1% in annualized terms. The loss rate in default $\kappa_d^N = 67\%$ is taken from Schwert (2020), which computes recovery rates for different debt instruments for a sample of firms from Moody's Ultimate Recovery Database.[27] I set non-bank monitoring intensity to $\overline{m} = 0$; as discussed above, this is simply a normalization.

**Firms** Panel B describes the external firm parameters. I choose the depreciation rate $\delta = 2.4\%$ to be consistent with the National Income and Product Accounts, following Begenau and Landvoigt (2022). I set the population share of non-corporate firms to $\tilde{\mu}_n = 30.4\%$, consistent with the measurements of Dyrda and Pugsley (2019) using detailed tax data.[28] Of the remaining corporate firms which are corporate, I assume that $\frac{\tilde{\mu}_a}{1-\tilde{\mu}_n} = 44.9\%$ are type $a$, consistent with the share of firms rated A- or higher in the sample of Kisgen (2006).

**Banks** Panel C describes the externally assigned bank parameters. I assume entrant banks' begin with no net worth, $n_0 = 0$.[29] I take the bank loan loss rate $\kappa_d^B = 17\%$ from Schwert (2020) for consistency with the non-bank loan loss rate; note that this implies that banks lose less in default than non-banks. Following Elenev et al. (2020), I assume that $\kappa_\varphi = 33.2\%$ of banks' net worth is lost upon exit.

[25] I choose the number for transparency and to trade off competing objectives. During the post-Financial Crisis period in which bank regulations have been analyzed most, low rates have been the norm; on the other hand, at the time of writing, interest rates are beginning to rise in the face of accelerating inflation. For a sample of Q1:1984 – Q1:2022, the average 1-year treasury rate is 3.68%; for Q4:2009 – Q1:2022, it is 0.66%.

[26] For example, Khan and Thomas (2003) set $A = 3.614$ and Khan and Thomas (2013) set $A = 2.15$.

[27] I use the mean recovery rates for first-lien term loans (bank) and senior unsecured bonds (non-bank). The former is the correct analog of a bank loan in the model; the latter is less clear since even the most senior bond is generally junior to loans.

[28] In Table 2 of Dyrda and Pugsley (2019), the authors find using Census data that 12.6% of firms partnerships and 17.8% of firms are sole proprietorships in the period 2005-2009.

[29] Note that entrants may also issue "startup" equity by choosing $e < 0$.

| | Parameter | | Value | Notes / Sources |
|---|---|---|---|---|
| **Panel A: Household** | discount factor | $\beta$ | 0.998 | ann. risk free rate of 1% |
| | coef. of relative risk aversion | $\gamma$ | 2 | standard |
| | labor disutility | $A$ | 2.5 | standard |
| | loss rate in default | $\kappa_d^N$ | 0.67 | Schwert (2020), Table 1 |
| | loan issuance cost | $\kappa_L$ | 0.0029 | 1% annualized |
| | monitoring intensity | $\overline{m}_N$ | 0 | normalization |
| **Panel B: Firms** | depreciation rate | $\delta$ | 0.024 | standard |
| | non-corporate firm share | $\tilde{\mu}_n$ | 0.304 | Dyrda and Pugsley (2019) |
| | A-rated share of corporates | $\frac{\tilde{\mu}_a}{1-\tilde{\mu}_n}$ | 0.44 | Kisgen (2006) |
| **Panel C: Banks** | initial bank net worth | $n_0$ | 0 | no initial net worth |
| | loss rate in default | $\kappa_d^B$ | 0.17 | Schwert (2020), Table 1 |
| | bank failure cost | $\kappa_\varphi$ | 0.332 | Elenev et al. (2020) |
| **Panel D: Government** | capital requirement | $\chi$ | 0.08 | Basel III |
| | gov't spending / GDP | $\frac{G}{Y}$ | 0.176 | Elenev et al. (2020) |
| | labor income tax rate | $\tau_n$ | 0.293 | Elenev et al. (2020) |
| | corporate profit tax rate | $\tau_\pi$ | 0.200 | Elenev et al. (2020) |
| | interest income tax rate | $\tau_d$ | 0.0315 | Elenev et al. (2020), annualized |
| | deposit insurance fee rate | $\kappa_d$ | 0.00084 | Elenev et al. (2020) |
| **Panel E: Aggregates** | average TFP | $\overline{z}$ | 1 | normalization |
| | share of recession periods | $\overline{Q}_R$ | 0.211 | share in postwar U.S. |
| | prob. exit recession | $Q_{RE'}$ | 0.167 | avg. duration 1.5 years |

Table 1: **Externally assigned parameters**

**Notes:** The model period is one quarter. This table presents the parameters of the model assigned externally, i.e. independently of solving for equilibrium. The right-most column contains information on the sourcing or implicit target for these parameters; for more details, see the discussions in Section 4.2 and Appendix B.

**Government** Panel D presents the government and regulatory parameters. The baseline capital requirement of $\chi = 8\%$ follows Basel II. Labor income, interest income, and profit taxes are $\tau_h = 29.3\%$, $\tau_d = 3.15\%$, and $\tau_\pi = 20\%$, respectively, following Elenev et al. (2020).[30] Likewise, I assume that government expenditures are 17.6% of GDP on average, and that the deposit insurance fee is $\kappa_d = 0.084\%$.

**Aggregate state processes** Finally, panel E describes the set of parameters relevant to my implementation of the exogenous components of the aggregate state. I assume that aggregate TFP follows a two state Markov process, $z \in \{z_E, z_R\}$ ($E$ = expansion, $R$ = recession), with transition matrix $Q_{zz'}$. I assume the ergodic distribution $\overline{Q}_z$ implied by $Q_{zz'}$ has $\overline{Q}_R = 21.1\%$, consistent with the frequency of recessions in the postwar U.S. I further assume that $Q_{RE'} = 1/6$, consistent with

[30] The interest income tax is converted into a quarterly rate for consistency; the annualized rate is 13.2%.

an average recession duration of 6 quarters. I normalize $\overline{z} = 1$, and calibrate the recession TFP level $z_R$ below to match the volatility of output.

### 4.2.2 Internally calibrated parameters

**Strategy** I calibrate the remaining parameters to match a rich set of empirical moments describing bank financing and corporate investment, default, and borrowing using Simulated Method of Moments (SMM). Unless otherwise noted, all moments are averages from 2009Q1 to 2021Q4; this provides a reasonably long sample while removing some of the longer term trends in key targets over prior decades. These target moments and parameters are presented in Panels A and B of Table 2, respectively.[31] All parameters are determined jointly, and so the discussion of the relationships between parameters and moments in this section is intended to be intuitive and descriptive. Given that the targets come from different data sets, computing standard errors for my parameter estimates is infeasible. In lieu of these, and to formalize the discussion found here, Appendix C.2 presents a sensitivity analysis following Andrews et al. (2017).

**Macro targets** Panel A.1 of Table 2 describes the key aggregates I require my model to match. Since one of the main concerns for macroprudential policy is stabilization of business cycles, I match the overall volatility of output in the data (1.03%). Additionally, to insure that the links between debt financing, capital, and production are consistent with the data, I match three key output ratios: capital to output (2.2), investment to output (0.17 annualized), and business debt to output (0.72). Finally, I target the labor share of income to insure an empirically consistent labor margin.

**Bank targets** Panel A.2 of Table 2 lists six key target moments describing banks' financing, lending, and failure patterns. With respect to financing, since capital requirements act directly on bank leverage, the model must match banks' observed high leverage (0.92). In addition, I require that my model match key flow financing patterns: banks' gross equity issuance rate of 1.1% and a net dividend payout rate of 5.8%, computed following Baron (2020) and Elenev et al. (2020). The former moment captures the frequency and magnitude of bank equity issuance, that is, the rate at which issuance costs are incurred. The latter moment captures the average rate at which earnings from lending leave the banking sector, shaping banks' use of external funds.

I require further that the model match banks' average flow profitability, captured by average net interest margin (3.26%), given the loan risk implied by the chargeoff rate. Finally, since avoidance of costly bank failures is a primary concern for regulators, I target the quarterly bank failure rate (0.74%). Many moments from the set of firm targets discussed below (bank share of corporate debt, business debt to GDP, etc.) are also informative for the banking sector.

**Firm targets** Panel A.3 of Table 2 describes the firm moments I target. Since a change in capital requirements impacts aggregates via firms' financing patterns in the model, the model must match

[31] Appendix B contains detailed information on the sources and construction of each target moment, as well as their definitions in model notation. Appendix C.1 contains the computational algorithm used to solve the model.

the composition of financing both in aggregate and by firm type. I target three moments concerning firms' leverage: sectoral leverage for corporates (0.41) and non-corporates (0.42), as well as the ratio of median B-rated firm leverage to median A-rated firm leverage (1.26). The former two moments come from Flow of Funds data, which does not disentangle firm types within the corporate sector. Therefore, I draw the latter moment from Kisgen (2006). Conditional on overall leverage, I must also capture the composition of firms' debt by lender. By construction, all non-corporate debt comes from banks, and the share of total corporate debt accounted for by bank loans averages 0.34.

In order to study aggregate investment with firm heterogeneity, the model must also match the composition of total debt, productive capital, and risk across firm types. The corporate shares of total debt and total capital average 0.62 and 0.63, respectively. Banks lend to both corporate and non-corporate firms, and my analysis hinges on banks' lending responses to changes in capital requirements across their loan portfolios. Therefore, it is important to match the share of total bank lending to corporate (versus non-corporate) firms, 0.38. Finally, I target three moments that describe firms' riskiness. For corporate firms, I target average corporate bond spreads for A-rated (1.62%) and B-rated (2.71%) firms. In order to capture non-corporate firms' average riskiness, I match banks' average chargeoff rate on C&I loans (0.65%).[32]

**Parameters and model fit** Table 2 describes the parameters which I calibrate to the targets described above. Given limited ability to measure key sample moments by type within the corporate sector, and to reduce the total number of parameters to estimate, I assume that both A- and B-rated corporate firms have the same overall returns to scale, standard deviation of productivity shocks, and diversion rate, but allow their capital shares and and endowments to differ. I assume all three firm types have the same mean diversion benefit. This allows for differences in leverage and risk among corporates which I can map to the data. Together with the parameters directly affecting banks only, this implies a total of nineteen internally calibrated parameters.[33]

Firms' production parameters $\alpha_j$ $\eta_j$ are closely linked to most target moments, particularly output and labor ratios. I find that all firm types have similar capital shares, but that non-corporates have a modestly higher overall returns to scale. Among corporates, B-rated firms have 6.7% higher capital shares than A-rated ones, contributing to their higher leverage and bond spreads (see below). This set of parameters leads to a reasonable fit on all standard aggregate output ratios, with the caveat that the model's business debt to GDP ratio is somewhat high.

Conditional on key aggregates and production parameters, leverage and risk moments help inform the remaining elements of the firm parameter vectors $\Theta_j$. Given $\eta_j$ and $\alpha_j$, productivity risk $\sigma_{\varepsilon j}$ determines firms' unconstrained optimal capital.[34] Then, endowments $\overline{k}_j$ and external financing costs

[32]In both the model and the data, this moment (as well as the net interest margin) combines loans to corporate and non-corporate firms. Since I match bond spreads and account for differences in recovery rates, though, this moment is still quite informative about the riskiness of bank loans relative to other loans.

[33]The type-specific parameter vector $\Theta_j$ has six elements for each firm; imposing $\eta_a = \eta_b$, $\overline{\sigma}_{\varepsilon a} = \overline{\sigma}_{\varepsilon b}$, $\omega_a = \omega_b = \omega_c$, and $\theta_a = \theta_b$ reduces the total number of $\Theta$ parameters from eighteen to thirteen. Keeping the risk and moral hazard parameters constant within the corporate sector disciplines the model so that differences in default and prices among corporates are attributable to more readily observed differences in leverage and financing composition.

[34]I assume firm's productivity risk does not depend on aggregate TFP; that is, $\sigma_{\varepsilon j}(z) = \sigma_{\varepsilon j}$ for all $z$.

| **Panel A: Target moments** | | |
|---|---|---|
| **Moment** | **Data** | **Model** |
| **A.1 Macro** | | |
| Output volatility (%) | 1.03 | 1.05 |
| Capital to output ratio | 2.20 | 2.09 |
| Investment to output ratio | 0.17 | 0.22 |
| Business debt to GDP ratio | 0.72 | 0.86 |
| Labor share of income | 0.58 | 0.52 |
| **A.2 Banks** | | |
| Bank leverage | 0.92 | 0.92 |
| Gross equity iss. rate (%) | 1.10 | 0.32 |
| Net dividend payout rate (%) | 5.80 | 0.34 |
| C&I net interest margin (ann. %) | 3.26 | 4.26 |
| C&I charge-off rate (%) | 0.65 | 0.08 |
| Bank failure rate (quarterly %) | 0.74 | 0.79 |
| **A.3 Firms** | | |
| Corporate leverage | 0.41 | 0.41 |
| Non-Corporate leverage | 0.42 | 0.42 |
| A-Corp / B-Corp leverage ratio | 1.26 | 1.40 |
| Corp bank debt / Total Corp debt | 0.34 | 0.38 |
| Corp bank debt / Total bank debt | 0.38 | 0.41 |
| Total Corp debt / Total debt | 0.62 | 0.64 |
| Total Corp capital / Total capital | 0.63 | 0.65 |
| A-Corp bond spread (ann. %) | 1.62 | 1.74 |
| B-Corp bond spread (ann. %) | 2.71 | 2.79 |

| **Panel B: Calibrated parameters** | | |
|---|---|---|
| **Parameter** | | **Value** |
| Corp returns to scale | $\eta_c$ | 0.57 |
| Non-Corp returns to scale | $\eta_n$ | 0.69 |
| A-Corp capital share | $\alpha_a$ | 0.15 |
| B-Corp capital share | $\alpha_b$ | 0.16 |
| Capital share, Non-Corp | $\alpha_n$ | 0.14 |
| A-Corp endowment | $\bar{k}_a$ | 0.91 |
| B-Corp endowment | $\bar{k}_b$ | 0.61 |
| Non-Corp endowment | $\bar{k}_n$ | 0.90 |
| Corp SD productivity | $\sigma_{\varepsilon c}$ | 0.20 |
| Non-Corp SD productivity | $\sigma_{\varepsilon n}$ | 0.09 |
| Diversion benefit | $\omega$ | 0.14 |
| Corp diversion rate | $\theta_c$ | 0.83 |
| Non-Corp diversion rate | $\theta_n$ | 0.42 |
| Extreme value scale | $\zeta$ | 0.0016 |
| Recession TFP | $z_R$ | 0.984 |
| Equity issuance curvature | $\bar{\psi}$ | 0.08 |
| Mean entry cost | $\bar{\phi}_e$ | 0.18 |
| SD bank profit shocks | $\sigma_{\phi_p}$ | 0.0087 |
| Monitoring cost scale | $\bar{c}$ | 0.05 |

Table 2: **Target moments and internally calibrated parameters**

**Notes:** The model period is one quarter. Panel B of this table presents the parameters of the model calibrated internally to match the set of target moments in Panel A. For more details, see the discussions in Section 4.2 and Appendix B.

pin down their leverage. I find that corporates have higher productivity risk than non-corporates, $\sigma_{\varepsilon a} = \sigma_{\varepsilon b} > \sigma_{\varepsilon n}$. A-rated corporates and non-corporates have similar capital endowments, with B-rated corporates approximately 32% smaller: $\bar{k}_n \approx \bar{k}_a > \bar{k}_b$. Conditional on leverage and productivity risk, the moral hazard parameters $\omega$ and $\theta_j$ determine default and diversion incentives, which pin down the bond and loan spreads they face.[35] After imposing that the scale of diversion benefit is equal across firm types ($\omega_a = \omega_b = \omega_n$), I find that corporate managers can divert a larger share of profits than non-corporate managers ($\theta_a = \theta_b > \theta_n$).

Arguably the most critical parameter for my analysis is the substitutability parameter $\zeta$, which governs the elasticity of substitution between lenders for corporate firms in (6).[36] This parameter

[35] I assume that $x$ follows an exponential distribution with mean $\omega_j$.

[36] Along the *intensive* margin of loan demand, firms' full parameter vector $\Theta_j$, as well as the monitoring intensity of their lenders $m$, determine their optimal loan size for a given price $q$. Along the *extensive* margin, bank loan demand depends on the substitutability parameter (high $\zeta$ means the $\nu$ shocks have high variance). As the variance of this

is informed simultaneously by two key moments: the bank share of corporate debt and banks' net interest margin. The bank share depends on the value of the contracts available to firms at each type of lender and the degree of substitutability between lenders. Substitutability further determines the elasticity of demand for bank loans; given the competitive structure of the banking sector this moment is informed by banks' net interest margins. I find that corporates have significant substitutability: the mean value associated with the extreme value shocks is equal to less than 10 bps of the total equilibrium value of borrowing from either lender.[37] This implies that firms' lender choices are driven almost entirely by fundamentals, and therefore that banks must compete hard for corporate borrowers against the non-bank sector.

What do the estimated parameter vectors $\Theta_j$ imply about the quantitative behavior of the three types of firms? First, A- and B-rated corporates are similar except for their capital endowments. This implies that B-corporates have greater demand for leverage, making them riskier than their A-rated counterparts.[38] Second, non-corporate firms have even greater demand for debt than corporate firms. At the same time, though, they face lenders with greater effective market power, since they cannot substitute to non-bank lending. Therefore, in equilibrium, non-corporate firms are actually smaller than corporate firms in terms of total capital (debt plus endowment). Since non-corporates are small relative to their optimal scales, then, they are relatively low risk.[39]

Turning to banks, I assume the equity issuance cost function takes the form $\psi(e) = -\overline{\psi}\ln(1-e/\overline{\psi})$ if $e < 0$ and $\psi(e) = e$ otherwise.[40] The parameter $\overline{\psi}$ shapes the tradeoff between deposit and equity financing, and is consistent with sizable, positive costs of equity issuance; on average, banks pay costs equal to 1–2% of the amount of equity issued. This form delivers net payouts and gross equity issuance consistent with, but a bit lower than, what we see in the data. These costs combine with banks' access to cheap debt financing to keep bank leverage high in the model; for the vast majority of banks, the capital requirement binds. The entry cost distribution implies an entry rate approximately equal to the failure rate of 0.74% (on average over the cycle) and helps pin down the share of the loan market each bank gets, and therefore the range of bank net worth.

Finally, I assume banks' monitoring cost function is linear with scale $\bar{c}$: $c(m) = 1 + \bar{c}m$. The estimated $\bar{c}$ implies that eliminating 1% of moral hazard defaults raises the cost of lending by about 5 bps, consistent with banks finding it cheap to eliminate some moral hazard, but expensive to remove all or even most of it. Given the generally low costs of default in both the model and the data (see bond spread and chargeoff rate moments), monitoring effects are generally second order compared to price effects in the quantitative model.

shock increases (decreases), firms become less (more) sensitive to contract terms; that is, their loan demand becomes less (more) elastic along the extensive margin.

[37]The mean of the extreme value shocks are $\zeta\gamma_E \approx 0.0009$, where $\gamma_E$ is the Euler-Mascheroni constant. The equilibrium values $v_B$ and $v_N$ in (5) are on the order of 1.2, hence this result.

[38]For a visualization of this and other dynamics, see Figure C.1 in Appendix C.3.

[39]These opposing forces make it difficult to simultaneously match banks' NIM and the chargeoff rate.

[40]This specification is convex for $\overline{\psi} > 0$. This implies $\psi^{-1}(e) = \overline{\psi}(1 - \exp(-e/\overline{\psi}))$. This specification captures convex costs of equity issuance while imposing smoothness at the potential kink at $e = 0$ (since $\lim_{e\uparrow 0}(\psi^{-1})'(e) = \lim_{e\downarrow 0}(\psi^{-1})'(e) = 1$). Furthermore, $\lim_{\overline{\psi}\to\infty}\psi(e) = e$ for all $e$. This function is also easily invertible which eases computation. See Figure C.2 in Appendix C.3 for details.

### 4.3 Quantitative assessment of key frictions

In order to highlight key properties of the model ahead of the main results and provide additional intuition for how specific parameters help pin down key model moments, this section considers a series of parameter changes. I consider two sets of model variants, summarized in Table 3. The first set reduces each of the three key frictions in the model in turn: (i) firm-side moral hazard ("low MH"); (ii) bank-side moral hazard ("cheap monitoring"); and (iii) reduced equity issuance costs ("cheap equity").[41] The second set enhances competition in the banking sector in two ways: (i) by making substitution across lenders easier among corporate firms ("easy substitution") and (ii) reducing the costs of entry for banks ("cheap entry"). In each case, the parameter variation is small enough to keep the aggregate effects small and focus on distributional consequences. This section can be considered a quantitative analog of the discussion of assumptions in Section 3.6.

**Frictions** Reducing firm-side moral hazard (column [1]) reduces firms' default risk for a given amount of leverage (as documented in Figure 2(b)), but also induces firms to take on more leverage. The latter effect induces significant increases in bond spreads, boosting bank loan demand, as well as the chargeoff rate. To accommodate this increase in demand, bank net worth grows and more banks enter. This keeps banks' net interest margins basically stable, and so lending activity migrates into the banking sector. This leads to modest increases in debt, capital, and output across firm types.

Lowering the monitoring cost $\bar{c}$ (column [2]) behaves similarly, but on a much smaller scale and localized to bank lending. Banks respond by increasing monitoring, which counteracts the increased in diversion likelihood associated with higher leverage (see Figure 2(a)). This cuts the chargeoff rate markedly. Increased monitoring implies that banks can charge lower interest rates and still be compensated for risk, so the net interest margin falls. This raises total debt and causes an aggregate shift into bank lending.

Lowering bank equity issuance costs (increasing $\overline{\psi}$, column [3]) dampens banks' precautionary motives to build net worth. On the margin, banks are less constrained and therefore have higher charter values, and so more enter, and they fail at a lower rate. Because banks have less capital, they modestly increase their loan rates relative to the bond market, leading to a shift out of the banking sector among corporates.

**Competition** Reducing the extreme value scale parameter $\zeta$ (column [4]) increases firms' elasticity of demand for bank loans, increasing how much competition between banks face from the non-bank sector. On the other hand, lowering entry costs (mean $\overline{\phi}_e$, column [5]) lowers barriers to entry for competition and increases competition among banks for borrowers.

In both cases, the impacts are minimal because the baseline model is already quite competitive. The largest changes are observed in corporate debt composition and bank financing patterns. When

[41] Of course, the capital requirement is itself a key friction, but I omit this here since it is the sole focus of Section 5. Furthermore, it is in principle possible to reduce moral hazard on the bank side in other ways (for example, by removing limited liability); I choose the approach of reducing monitoring costs here to keep the focus on the component of banks' moral hazard that is novel to the present study.

| *pct. chg. rel. to baseline parameterization* | Low MH [1] | Cheap Monitor [2] | Cheap Equity [3] | Easy Subs [4] | Cheap Entry [5] |
|---|---|---|---|---|---|
| **Panel A: Macro** | | | | | |
| Total output | -0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total consumption | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total capital | 0.2 | 0.0 | 0.1 | 0.1 | 0.0 |
| **Panel B: Banks** | | | | | |
| Total bank lending | 5.9 | 2.2 | -0.3 | 1.7 | -0.3 |
| Total dividends | 4.4 | 2.9 | 0.8 | -0.3 | 2.2 |
| Mass of active banks | 1.0 | -1.3 | 3.6 | 0.4 | 1.4 |
| Average bank net worth | 5.1 | 2.2 | -0.2 | 1.5 | 0.1 |
| C&I net interest margin | -0.8 | -1.4 | 0.3 | -1.5 | 0.2 |
| C&I chargeoff rate | 7.3 | -5.3 | -1.3 | 2.6 | -0.5 |
| Bank failure rate | -1.3 | 0.8 | -3.3 | -0.4 | 3.1 |
| **Panel C: Firms** | | | | | |
| Total debt | 0.6 | 0.0 | 0.2 | 0.1 | 0.0 |
| Total Non-Corporate debt | 0.8 | 0.4 | 0.1 | 0.1 | 0.0 |
| Total Corporate debt | 0.2 | -0.6 | 0.6 | 0.2 | 0.1 |
| Corp bank debt / Total Corp debt | 13.3 | 5.9 | -1.6 | 3.7 | -0.9 |
| Corp bank debt / Total bank debt | 7.9 | 4.0 | -1.3 | 2.1 | -0.6 |
| Total Corp debt / Total debt | 0.2 | 0.3 | -0.2 | 0.0 | 0.0 |
| A-Corp bond spread | 23.9 | 4.0 | -1.7 | 1.3 | -0.7 |
| B-Corp bond spread | 14.8 | 2.9 | -1.1 | 1.0 | -0.4 |

Table 3: **Experiments to highlight the role of key model features**

**Notes:** Each column of this table presents the percentage point difference for the indicated moment (row) and model version (column) relative to the baseline parameterization from Table 2. Column [1] lowers the mean of the diversion benefit $\omega$ by 2%; column [2] lowers the monitoring cost $\bar{c}$ by 10%; column [3] raises the equity issuance cost curvature $\overline{\psi}$ by 5%; column [4] lowers the extreme value scale $\zeta$ by 5%; and column [5] reduces the average entry cost $\overline{\phi}_e$ by 5%.

substitution becomes easier for corporates, banks are forced to compete with non-banks more, and net interest margins fall. As a result, corporates actually shift more into bank lending. By contrast, when banks face lower entry costs, more banks enter and each bank commands a smaller share of the loan market, reducing charter values. As a result, even though competition conditional on a match is unaffected, banks build up less net worth and are effectively more constrained, causing them to increase loan rates (despite having more banks active). As a corollary, banks are quicker to pay out dividends and fail more often.

## 4.4 Validation

This section considers untargeted properties of the quantitative model motivated by two key questions. First, does the model generate firm financing patterns consistent with empirical regularities

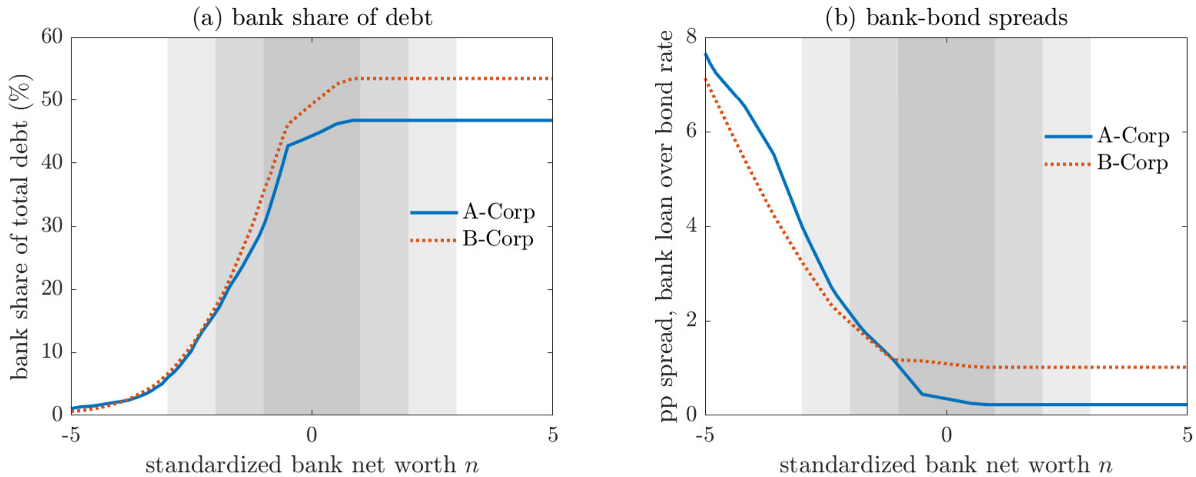


Figure 3: **Financing choices conditional on net worth of paired bank**

**Notes:** Each panel plots the indicated object against the standardized value of the net worth (under the average equilibrium distribution) of the firm's matched bank. For panel (b), the "bank-bond spread" is the difference between the (loan-weighted) loan rate charged by a bank with the indicated level of net worth and the equilibrium bond rate for the indicated firm type.

at the micro level? Second, does the model deliver business cycle dynamics that are consistent with both macroeconomic regularities and patterns within the financial and business sectors? Both help understand the aggregate responses to the regulatory changes considered in Section 5.

**Micro-level financing and pricing patterns** Since capital requirements act directly on banks' constraints, the model must deliver empirically consistent links between bank capitalization and firm borrowing. An extensive empirical literature, notably Becker and Ivashina (2014) and Schwert (2018), documents that firms who borrow from less-capitalized banks are more likely to issue bonds. Figure 3(a) shows that this holds endogenously in the model: for A-rated (B-rated) corporates, matching with a bank with net worth one standard deviation below the mean is associated with a 14.2 pp (13.9 pp) reduction in the bank share of debt.[42] Except at the most constrained banks, B-rated corporates source a larger share of their total debt from banks than A-rated corporates (4.5 pp on average). This is consistent with empirical evidence from Colla et al. (2013) and Rauh and Sufi (2010) that firms shift their capital structures toward bank loans as credit ratings decline.

Panel (b) reveals that this is driven by banks' constrained pricing decisions: banks with lower net worth charge higher interest rates. While unconstrained banks charge spreads over bond rates on the order of 1 pp, these spreads rise steadily, increasing to nearly 8 pp for the least capitalized. These pricing differences are consistent with the data, controlling for seniority. For example, the average loan-bond spread for A-corporates (B-corporates) is 1.1 pp (1.5 pp), consistent with the estimated range of 1.4 to 1.7 pp obtained in Schwert (2020).

[42] This is consistent with estimates in Becker and Ivashina (2014), although these authors use slightly different measures of bank loan supply than the net worth values employed here. For example, these authors find that a one standard deviation tightening of lending standards is associated with a 1.4 pp reduction in the fraction of total external financing coming from bank loans. It should be further noted that the explicit matching mechanism among bank-dependent firms discussed in Schwert (2018) is absent in the model given random matching.

| | Data | | | Model | | |
|---|---|---|---|---|---|---|
| | $\sigma_x/\sigma_y$ | $\rho_{xy}$ | $\rho_{xx'}$ | $\sigma_x/\sigma_y$ | $\rho_{xy}$ | $\rho_{xx'}$ |
| | [1] | [2] | [3] | [4] | [5] | [6] |
| **Panel A: Macro** | | | | | | |
| Total output | *1.03%* | *1.0* | 0.9 | *1.05%* | *1.0* | 0.3 |
| Total consumption | 0.8 | 0.9 | 0.9 | 0.4 | 0.2 | 0.9 |
| Total investment | 5.2 | 0.9 | 0.9 | 19.3 | 0.9 | 0.2 |
| **Panel B: Banks** | | | | | | |
| C&I net interest margin | 3.2 | 0.0 | 0.7 | 3.5 | 0.7 | 0.3 |
| C&I chargeoff rate | 43.4 | -0.5 | 0.7 | 2.9 | -0.7 | 0.2 |
| Bank failure rate | 0.4 | -0.1 | 0.6 | 3.1 | -0.2 | 0.9 |
| **Panel C: Firms** | | | | | | |
| Total debt | 2.7 | 0.3 | 1.0 | 1.6 | 0.3 | 0.7 |
| Non-Corporate debt | 2.9 | 0.3 | 1.0 | 3.2 | 0.0 | 0.7 |
| Corporate debt | 2.8 | 0.4 | 0.9 | 1.2 | 0.7 | 0.6 |
| Corporate bank debt | 3.9 | 0.4 | 0.9 | 4.8 | -0.5 | 0.5 |
| Corporate bond debt | 2.3 | -0.2 | 0.9 | 3.7 | 0.7 | 0.3 |
| Corp bank debt / Total Corp debt | 1.6 | 0.4 | 0.9 | 5.1 | -0.6 | 0.4 |
| A-Corp bond spread | 20.0 | -0.4 | 0.8 | 6.1 | 0.3 | -0.1 |
| B-Corp bond spread | 16.9 | -0.5 | 0.8 | 3.2 | 0.3 | -0.2 |

Table 4: **Business cycle properties: model vs data**

**Notes:** Columns [1] - [3] present the volatility relative to GDP ($\sigma_x/\sigma_y$), correlation with GDP ($\rho_{xy}$), and autocorrelation ($\rho_{xx'}$) of the indicated (logged, HP-filtered) moment for the model; columns [4] - [6] present the analogs for the data (see Appendix B for a description of the relevant series).

**Business cycle moments** While time series averages suffice to inform key parameters, some impacts of changing capital requirements may play out over the business cycle. For example, costly bank failures may be concentrated in recessions, straining resources especially during downturns. Therefore, Table 4 compares selected business cycle properties of the model to the data, focusing on aggregate, bank, and firm outcomes in Panels A, B, and Panel C, respectively.

Panel A shows that the model performs quite well with regards to standard macroeconomic aggregates. We observe familiar patterns in the model: consumption and investment are procyclical and persistent, with the volatility of these metrics relative to output falling in line with the data with two exceptions. As is typical with representative household models, consumption is considerably less volatile and procyclical in the model than in the data. In addition, investment is even more volatile, given the lack of adjustment costs and irreversibilities in the model.

Turning to the banking sector in Panel B, the model matches the empirical countercyclicality of both bank failures and chargeoffs on bank loans. Despite matching the net interest margin's volatility, the model misses its acyclicality.

Finally, Panel C shows that the model captures key cyclical properties of firms' financing. Total, corporate, and non-corporate debt are all procyclical, highly persistent, and more volatile than output. Corporate debt is strongly procyclical, indicating a role for sectoral reallocation of financing over the cycle. Within the corporate sector, the model matches the relative volatility of not only total debt, but also lender-specific debt; notably, the model captures the fact that corporate bank debt is much more volatile than either total or bond debt. One shortcoming of the model is that its bond spreads are weakly procyclical, as opposed to weakly countercyclical in the data.

# 5 Effects of Increasing Capital Requirements

This section presents the aggregate, equilibrium effects of changing capital requirements in the model. Section 5.1 studies average long run effects by comparing equilibria under several capital requirements. A key theme of these results is that the *aggregate* impacts of capital requirement changes are small in the long run, even though the sectoral or compositional impacts may be sizable. Section 5.3 demonstrates the robustness of the main findings to perturbations of key elements of the model. Section 5.4 provides a brief discussion of the key takeaways from these analyses.

## 5.1 Long run average effects

Table 5 summarizes the key long run results of varying the capital requirement. Though I consider a wide range of capital requirements, I report results for only five levels, all relative to the baseline of 8%: 1%, 5%, 10%, 15%, and 20%. I present my results in three phases: (i) top line macro aggregates; (ii) effects on banks; and (iii) effects on firms. I close with some brief remarks on business cycles and transitions across regulatory regimes.

**Macro aggregates** Panel A of Table 5 shows how the level of the capital requirement affects key macroeconomic aggregates. The effect of raising the capital requirement on output is uniformly small in magnitude, though non-monotone in direction: changing the capital requirement to 1% (20%) raises average output only 0.2% (0.1%) relative to the baseline. While aggregate consumption decreases monotonically with the capital requirement, the magnitude of this effect is of similarly small magnitude. Correspondingly, total welfare effects are modest, on the order of tenths of percentage points in consumption equivalent units.

Still it is worth noting that welfare has a clear hump shape in the capital requirement, with a peak at 9%. What delivers this hump shape? As the capital requirement falls, consumption and labor both increase; the former increases welfare, while the latter decreases it. If the marginal unit of increased labor supply translated efficiently into consumption, then, the household would strictly prefer a low capital requirement since labor supply is frictionless. This is not the case, though, since low capital requirements come with the additional costs associated with increased bank failures (both deposit insurance and startup costs of new banks). Raising the capital requirement mitigates these costs. Trading off these forces, then, gives rise to an interior optimum for welfare.

| *pct chg. rel. to 8% CR for CR =* | **1%** [1] | **5%** [2] | **10%** [3] | **15%** [4] | **20%** [5] |
|---|---|---|---|---|---|
| **Panel A: Macro** | | | | | |
| Total output | 0.2 | 0.0 | 0.0 | 0.1 | 0.1 |
| Total consumption | 0.0 | 0.0 | 0.0 | -0.1 | -0.1 |
| Total capital | 0.4 | 0.1 | 0.1 | 0.1 | 0.2 |
| *Welfare (consumption equiv, pp)* | *-0.2* | *-0.1* | *0.0* | *-0.2* | *-0.2* |
| **Panel B: Banks** | | | | | |
| Sectoral leverage | 7.1 | 3.1 | -2.1 | -7.4 | -12.7 |
| Total bank lending | -0.5 | 0.0 | 1.2 | -3.3 | 1.5 |
| Total dividends | -18.7 | -0.8 | -3.7 | -17.0 | -23.2 |
| Mass of active banks | 23.2 | 2.3 | 4.3 | 17.3 | 29.1 |
| Average bank net worth | -68.8 | -30.2 | 21.5 | 66.5 | 126.0 |
| Average monitoring intensity | -38.6 | -18.2 | 9.7 | 37.9 | 55.9 |
| C&I net interest margin | 7.8 | 3.5 | -3.8 | -8.2 | -16.9 |
| C&I chargeoff rate | -12.8 | -7.4 | 4.9 | 19.4 | 34.6 |
| Bank failure rate | -12.3 | 0.3 | -4.9 | -15.6 | -23.9 |
| Bank failures | 8.0 | 2.6 | -0.8 | -1.0 | -1.8 |
| **Panel C: Firms** | | | | | |
| Total debt | 1.0 | 0.2 | 0.2 | 0.2 | 0.6 |
| Total Non-Corporate debt | -2.0 | -1.5 | 1.1 | 6.5 | 7.8 |
| Total Corporate debt | 6.5 | 3.4 | -1.5 | -11.1 | -12.4 |
| Corp bank debt / Total Corp debt | -8.3 | -3.5 | 4.1 | 1.8 | 13.0 |
| Corp bank debt / Total bank debt | -10.4 | -5.0 | 3.9 | 11.6 | 19.7 |
| Total Corp debt / Total debt | -3.0 | -1.8 | 0.9 | 6.2 | 7.1 |
| A-Corp bond spread | 6.4 | 5.5 | -2.3 | -35.8 | -36.9 |
| B-Corp bond spread | 4.8 | 4.4 | -1.7 | -20.1 | -20.9 |

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

**Notes***:* All moments, unless otherwise indicated, are long run averages under the indicated capital requirement, presented as percentage point deviations from the same moment under the baseline capital requirement of 8%. The welfare criterion is a weighted average consumption equivalent; positive numbers indicate that the representative household prefers the indicated capital requirement to the 8% baseline.

In order to understand why these aggregate impacts are so small, it is useful to recognize that the transmission of a change in the level of the capital requirement to aggregate investment has three key links: (i) a direct effect on bank leverage and financing policies; (ii) implied responses in lending policies across the distribution of banks; and (iii) implied changes for firms' capital structure and investment patterns. The remainder of this section quantifies the links in this chain sequentially.

**Bank financing** Since the capital requirement almost always binds, bank leverage decreases almost one-for-one with the capital requirement. Banks respond by building up capital: for example, increasing the capital requirement by just 2 pp (to 10%) induces a 21.7% increase in banks' average net worth. Banks achieve this by cutting deposits and dividends while issuing equity more frequently. This mechanism is critical: tighter capital requirements induce banks to retain earnings in order to finance loans with more internal capital.

Given reduced leverage and increased capital buffers, the quantity of bank failures decreases in the capital requirement. Though the avoided failures are enough to increase welfare when raising the capital requirement from its baseline level, the actual number of failures avoided is modest: increasing the capital requirement to all the way to 20% reduces the amount of failures by only 1.9%.[43] This comes from the fact that larger-than-expected loan losses drive only a portion of bank failures, with the rest coming from idiosyncratic profit shocks; the capital requirement imposes a buffer against loan losses, but not necessarily these other losses.[44] Despite a tighter constraint, increasing the capital requirement also increases the amount of banks active: this is driven by general equilibrium forces which are particularly expansionary for corporate firms, raising loan demand and therefore increasing charter values. These results imply that raising the capital requirement may actually promote competition within the banking sector.

**Bank lending** How do banks changes their lending policies alongside these changes in their financing policies? Total bank lending remains roughly flat as the capital requirement increases, despite the stark shifts in financing discussed above. This result balances three main forces. On the one hand, banks face tighter constraints, and therefore would like to increase loan rates and contract loan supply. This is counteracted, however, by banks' accumulation of net worth. Non-corporate firms are impacted only by these two forces; since the former dominates, there is a sharp contraction within this sector. For corporates, a third force is at play: a decline in bond spreads stemming from the reduction in overall volatility. This induces banks matched with corporates to lower loan rates to remain competitive. Together with the increase in net worth, this dominates the first effect and delivers an expansion to the corporate sector. Thus, although the top line effect on total bank credit is small, there is significant reallocation. Additionally, even though monitoring intensity increases sharply, the increased firm leverage associated with lower rates on average ends up increasing loan risk (as seen in the chargeoff rate). Since banks expend the majority of monitoring effort on B-Corporates in equilibrium, this effect is concentrated most among these firms.[45]

To summarize, the changes in bank lending associated with higher capital requirements combine two main effects: one from bank policies in isolation, the other from a two-part general equilibrium effect. First, for a given level of net worth, a bank that is constrained under a loose capital requirement is more constrained under a tight one, leading it to cut loan supply. The range of net worth levels for which banks are constrained also expands. In isolation, this effect would drive much larger

[43] Note that since the total mass of banks also endogenously responds to the capital requirement, this does not necessarily imply that the failure *rate* decreases monotonically in the capital requirement, due to a denominator effect. For example, at a capital requirement of 20%, the 1.9% reduction in failures corresponds to a 23.9% reduction in the failure rate, given the 28.9% increase in the mass of banks active in equilibrium.

[44] This result could possibly be changed if the profit shocks were modeled instead as idiosyncratic returns on an endowed portfolio of assets that also needed to be financed.

[45] For an illustration of banks' policies over net worth and capital requirements, see Appendix Figure C.3.

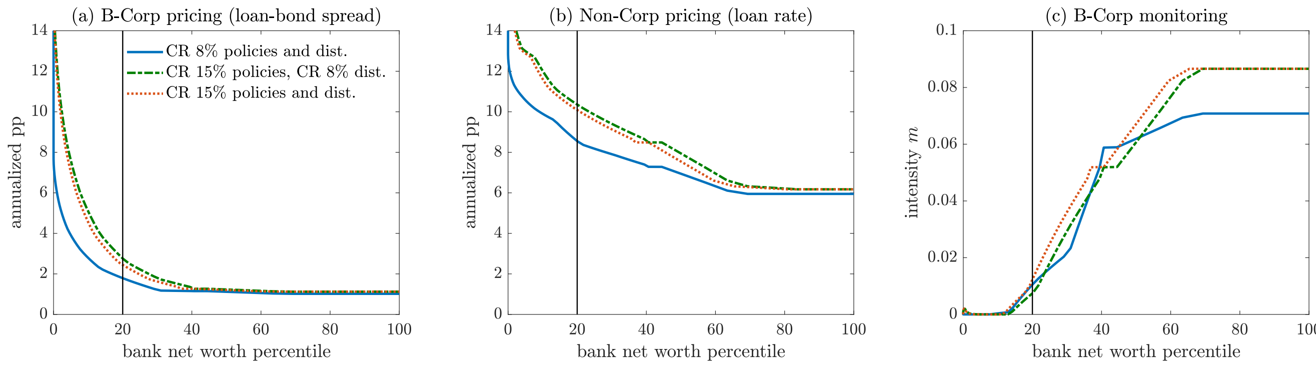


Figure 4: **Changes in select bank policies and distribution from 8% CR to 15% CR**

**Notes***:* In each figure, the blue solid (red dotted) line corresponds to the banks' firm-type-specific policy indicated in the title given the percentile of net worth in the equilibrium bank distribution under a capital requirement of 8% (15%). The green dashed lines plot the 8% capital requirement policies translated onto the 15% distribution of bank net worth. The vertical line at the 20th percentile is an indicator to aid the discussion in the main text.

aggregate changes than those observed in Table 5. Equilibrium effects, however, dampen this: banks change their financing policies such that the distribution of bank net worth shifts right, and extra competition coming from a decline in bond spreads further boosts corporate lending.

Figure 4 highlights these forces using pricing and monitoring policies for B-Corporates (panels (a) and (c)), and pricing for Non-Corporates (b). For example, the change in *bank policies alone* (blue solid line to green dashed line) implies that a bank with net worth at the 20th percentile increases B-Corporate loan-bond spreads by 98 bps in annualized terms. Opposing this, the *shift in the distribution of net worth* dampens this by 32 bps, for a net increase of 66 bps. This change in loan-bond spread is further offset by a 55 bp drop in bond rates, leading to an 11 bp total cost increase. The analogous calculation for Non-Corporates reveals a policy increase of 180 bps dampened by 27 bps for a net increase of 153 bps, much larger than the B-Corporate response and unmitigated by changes in bond rates. These effects play out similarly for all but the highest net worth, effectively unconstrained banks, which suggests that the disciplining role of borrower substitution is central to shaping banks' responses. Panel (c) shows that a similar dynamic plays out for monitoring: the tighter capital requirement induces more monitoring for a given level of net worth, which is amplified by the rightward shift in the net worth distribution.

**Firms' financing and investment** Finally, how do these changes in banks' lending policies affect firms' financing and investment patterns? These results are presented in Panel C of Table 5. Economy-wide business debt remains essentially flat given the counteracting forces described above. At each capital requirement, though, this reduction in total debt masks significant reallocation to the corporate sector, driven by: (i) drops in bond rates; (ii) these firms' ability to substitute; and (iii) banks' optimal responses to this substitution. On net, the bank share of corporate debt actually increases as the capital requirement is tightened. Non-corporate firms, though, experience a significant contraction. Even as corporate borrowing from banks declines, though, bank lending shifts towards corporate firms, underscoring how pronounced the contraction is for non-corporates.

| | *pct change, 15% CR relative to baseline 8% CR* | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Total** | **By firm** | | | **By lender** | | **By firm-lender match** | | | |
| **Firm type** | | A-C | B-C | Non | all | all | A-C | A-C | B-C | B-C |
| **Lender type** | | all | all | all | bank | bond | bank | bond | bank | bond |
| | [1] | [2] | [3] | [4] | [5] | [6] | [7] | [8] | [9] | [10] |
| Output | 0.1 | 0.6 | 0.5 | -1.0 | 0.0 | 0.2 | 3.9 | -1.3 | -0.8 | 1.4 |
| Capital | 0.1 | 2.9 | 2.4 | -4.7 | -1.1 | 1.9 | 6.8 | 0.7 | 1.3 | 3.1 |
| Debt | 0.2 | 8.7 | 5.0 | -11.1 | -3.3 | 5.5 | 14.4 | 5.5 | 4.2 | 5.6 |
| Borrowing rate | -8.5 | -24.6 | -12.0 | 6.0 | -3.4 | -17.2 | -27.8 | -22.6 | -9.0 | -14.4 |

Table 6: **Detailed impacts of raising capital requirement to 15% by firm type**

**Notes***:* All moments are presented as the percent change in the indicated moment under a 15% capital requirement relative to the same moment under an 8% capital requirement. The loan rate is weighted by total debt in each case; for example, in columns [2] – [4] the loan rate is the loan-weighted average borrowing cost for each firm type, while in columns [5] – [6] the loan rate is the loan-weighted average borrowing cost at each lender, weighting across firm types. A-C and B-C refer to A- and B-rated corporates, respectively, while Non refers to non-corporates.

In order to understand how a higher capital requirement affects each firm type differently, Table 6 compares firm performance and sorting by firm type, by lender, and by firm-lender match under a capital requirement of 15% relative to the baseline of 8%. The results in column [1] echo those from Table 5. Columns [2] – [4] highlight that the largest and most negative impacts are borne by non-corporate firms, whose debt drops 11.1% in response to a 6.0% increase in borrowing costs, causing them to have less capital, hire less labor, and ultimately reduce output by 1.0%. At the same time, corporate firms benefit from a pronounced decrease in borrowing costs as discussed above.

Comparing columns [5] and [6] clarifies these dynamics. In total, the activity of firms borrowing from banks declines due to increased borrowing costs, but is not fully soaked up by the non-bank sector: the near-zero aggregate change in total output, for instance, combines modest growth in the both the bank and non-bank sectors. Despite the drop in bond rates, the better-capitalized banking sector's incentive to compete for borrowers actually leads to growth among banked firms, highlighting the role of borrower substitution.

Finally, columns [7] – [10] complete this picture by analyzing how outcomes change conditional on both firm type and lender type among corporate firms (who can substitute). Since A-rated firms rely more on non-bank financing, the drop in bond rates – and corresponding increase in bank competition – are most strongly expansionary for these firms: their activity tends to flow *into* the banking sector in response to the stricter regulation. For B-rated firms for whom this effect is weaker, there is actually net substitution *out of* the banking sector, underscoring the scope for subtle dynamics across firm types.

## 5.2 Other effects

**Business cycles** To this point, I have found small long run aggregate effects *on average*. It is possible, though, that changing capital requirements may appreciably alter the business cycle. I do not find that this is the case.[46] The main novel dynamic which plays out over the business cycle is the interplay between firms' substitution and bank stability. Under a tighter capital requirement, fewer banks fail as a result of the loan losses which accrue when the economy enters a recession, which stabilizes the economy relative to the baseline capital requirement. However, these remaining banks are more financially constrained and therefore offer borrowers less favorable loan terms, amplifying the contraction. This leads to more volatility among non-corporate firms and more substitution among corporates under the higher capital requirement. Neither effect is quantitatively large, though, and the fact that they oppose each other leads to very small changes on net.

**Transitions between capital requirement regimes** Another potential concern for the implementation of regulatory changes is how the economy *adjusts* from one regulatory regime to another; in principle, a too-costly transition could undo any long-run gains from changing capital requirements. I find, however, that this adjustment is quite smooth, particularly if banks are given a "phase-in" period between announcement and implementation. Thus, the evolution along the transition path is governed by the same basic forces as the long run results, and that the magnitudes of changes along the transition path do not differ markedly from their long run levels.[47] For example, despite cuts in bank dividends to build financial capital to meet the new tighter capital requirement, consumption is generally only 2-3 bps below its original level during the implementation phase.

**Resilience after a financial shock** The model considered in this paper features fairly standard business cycle elements: the only exogenous aggregate shock is *real* (to total factor productivity). One of the primary concerns of regulators, however, is how the regulatory regime promotes stability in the wake of a *financial* shock. To study this, I simulate a one-time unanticipated "financial crisis" which wipes out 25% of all banks' net worth under the baseline capital requirement of 8%. I then simulate the same size shock under a 15% capital requirement.[48] Figure 5 plots the results of this experiment, averaged across 1,000 simulations in each case.

As one might expect, the impact of the shock is muted under stricter regulation. For example, the initial drop in consumption is 26 bps smaller under a capital requirement of 15% than 8%. The dynamics of aggregate capital and debt mirror those of consumption. Turning to the financial sector, the key difference is that there is a much smaller spike in bank failures, and therefore a much smaller dip in the total number of banks active, under the tighter capital requirement. These failure dynamics also imply that there is less amplification through exit of the initial, "fundamental" drop

[46]For concrete numbers, Appendix Table C.3 compares business cycle properties of key model variables between capital requirements of 8% (the baseline) and 15%.

[47]As a result, I relegate the detailed analysis of the transition path to Appendix C.3, in particular Figure C.4.

[48]Controlling for the increased net worth of the banking sector in this case implies that 14.9% of total net worth is wiped out for banks under the higher capital requirement.

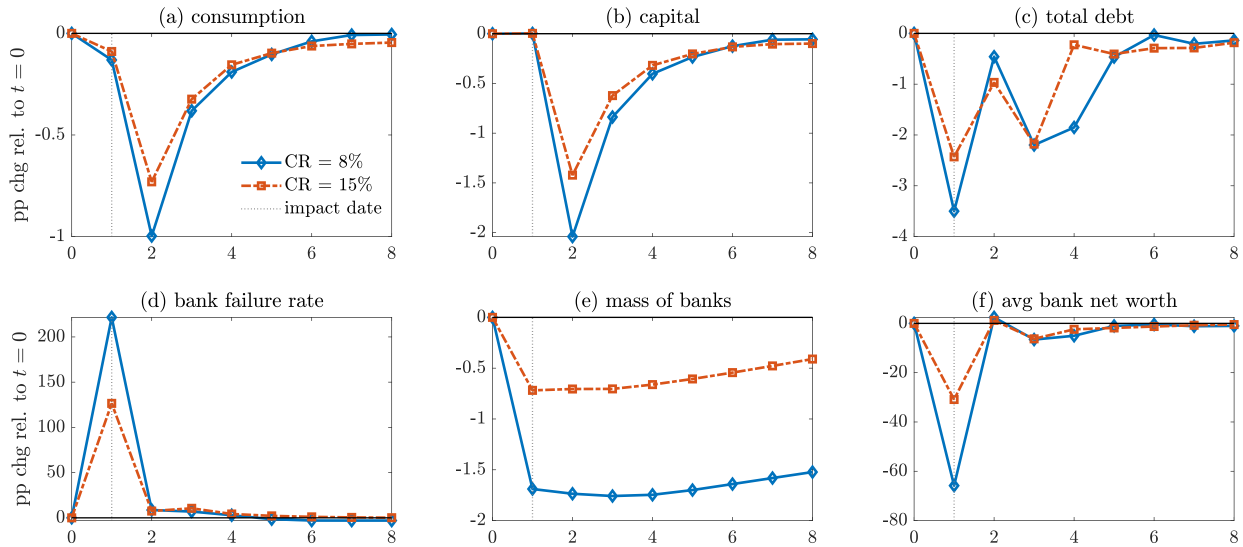


Figure 5: **Response to negative bank net worth shock under 8% and 15% CR**

**Notes***:* In each figure, the blue solid (red dotted) line corresponds to the average response, relative to the date before the shock hits, of the indicated variable for the 8% (15%) capital requirement economy. Responses are simulated 1,000 times and then averaged.

in net worth. Although the results depict a single shock, this of course implies that the banking sector – and therefore the wider economy – would be in better shape to withstand subsequent shocks under the tighter capital requirement.

### 5.3 Key frictions and the impacts of capital requirements

Section 4.3 explored how changing key model parameters affects the model economy under the baseline capital requirement. This section considers how these alternative economies respond to a change in the capital requirement from the baseline 8% to 15%. The results of this analysis are presented in Table 7. I find little evidence that changing the severity of the key frictions in the model modestly (i.e. in the neighborhood of the estimated parameters) changes the response to an increase in capital requirements.

Panel A reveals that all key macroeconomic aggregates have the same differential response to the tightened regulation to the tenth of a percentage point level, including welfare effects. Panels B and C document that although there are some large compositional changes within the banking and business sectors, the differences across variants of the baseline model along these dimensions are similarly small and mostly explained by baseline effects. The nature of these differences are very intuitive: for example, the biggest reduction in dividends occurs in the cheap equity model (column [4]), where dividends are higher on average to begin with. Similarly, the increase in monitoring is smallest in the cheap monitoring model (column [3]), where the base level of monitoring is already quite high.

Aside from these modest differences, though, the main dynamics from the baseline model are remarkably robust, even despite the differences in baselines documented in Table 3. Banks respond

| **pct. chg. under 15% CR relative to 8% CR for indicated model variant** | base [1] | low MH [2] | cheap monitor [3] | cheap equity [4] | easy subs [5] | cheap entry [6] |
|---|---|---|---|---|---|---|
| **Panel A: Macro** | | | | | | |
| Total output | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Total consumption | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 |
| Total capital | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| *Welfare (cons. equiv, pps)* | *-0.2* | *-0.2* | *-0.2* | *-0.2* | *-0.2* | *-0.2* |
| **Panel B: Banks** | | | | | | |
| Sectoral leverage | -7.4 | -7.4 | -7.4 | -7.4 | -7.4 | -7.4 |
| Total bank lending | -3.3 | -2.4 | -2.7 | -3.1 | -3.4 | -3.6 |
| Total dividends | -17.0 | -14.9 | -19.2 | -18.9 | -17.2 | -16.9 |
| Mass of active banks | 17.3 | 17.1 | 20.9 | 19.8 | 17.5 | 17.3 |
| Average bank net worth | 66.5 | 68.9 | 67.4 | 67.1 | 66.4 | 65.5 |
| Average monitoring intensity | 37.9 | 40.0 | 9.9 | 36.7 | 33.6 | 38.3 |
| C&I net interest margin | -8.2 | -7.9 | -8.3 | -7.7 | -8.3 | -7.9 |
| C&I chargeoff rate | 19.4 | 16.9 | 24.1 | 18.9 | 20.2 | 19.0 |
| Bank failure rate | -15.6 | -15.8 | -17.8 | -16.9 | -15.7 | -15.6 |
| **Panel C: Firms** | | | | | | |
| Total debt | 0.2 | 0.2 | 0.4 | 0.3 | 0.2 | 0.1 |
| Total Non-Corporate debt | 6.5 | 5.7 | 6.0 | 6.4 | 6.4 | 6.6 |
| Total Corporate debt | -11.1 | -9.6 | -9.8 | -10.5 | -11.1 | -11.4 |
| Corp bank debt / Total Corp debt | 1.8 | 1.2 | 1.4 | 1.8 | 1.2 | 1.5 |
| Corp bank debt / Total bank debt | 11.6 | 9.3 | 9.8 | 11.2 | 11.0 | 11.7 |
| Total Corp debt / Total debt | 6.2 | 5.4 | 5.5 | 6.0 | 6.2 | 6.4 |

Table 7: **Effect of raising capital requirement from 8% to 15% across model variants**

**Notes***:* All moments are percentage point deviations under a 15% vs an 8% capital requirement for the indicated model variant. The welfare criterion is a weighted average consumption equivalent; positive numbers indicate that the household prefers the 15% capital requirement to 8%.

to the stricter regulation by markedly increasing their net worth, cutting deposits, dividends, and loan supply to non-corporate firms. Corporate firms are largely able to weather any issues through substitution, while non-corporate firms bear the brunt of the adjustment. As a result, the share of economic activity becomes more concentrated in the corporate sector.

## 5.4 Discussion: what could deliver large effects?

The analysis in this section has been largely descriptive: what happens in the baseline model and several related variants when we change capital requirements? Across the board, I find only modest aggregate effects despite some significant reallocation within the business and banking sectors. Section 5.3 establishes that even material changes to key estimated parameters do not materially change this message. To firm up these insights, it is useful to ask: what about the model would have to change in order to get large effects? This section considers several possible avenues, from major parameter changes to fundamental changes to the model itself.

**Moral hazard and monitoring** Firms' modest leverage and the low estimated degree of moral hazard implies that the effective degree of moral hazard in the model is quite small.[49] Therefore, even though the private *cost* of mitigating moral hazard is low, the (private and social) *benefits* of doing so are also low. As a result, banks compete primarily on price with the competitive non-bank sector. If the extent of moral hazard were larger, there would be scope for banks to compete differently, offering a contract with both a high interest rate and high monitoring. Since both price and monitoring fall when the bank is constrained, it is possible that tightening the capital requirement in this setting could generate somewhat bigger effects. Ultimately, though, it is far from clear whether there is evidence for such a degree of moral hazard in the data. Moreover, this could have the effect of simply amplifying the increased accumulation of bank net worth that drives a lot of the dynamics in the baseline model.

**Competition** Equation (6) highlights that banks and non-banks compete on contract *value*, rather than any one contract *term*. Even though the bond market recovers less in default than banks and cannot monitor, it is still able to offer attractive enough loan terms to borrowers to keep bank loan demand highly elastic in the corporate sector. Therefore, unless banks become able to offer systematically higher value contracts to firms than non-banks, it is unlikely that this competitive discipline would go away. If banks competed more directly with each other, or even with a shadow banking sector, this disciplining effect would be even further strengthened.

In order to deliver larger effects from changing capital requirements, then, the model would have to move in the direction of *less* competition. Given the breadth of financing options available to corporate firms in practice, this is implausible for this sector. To see the impact of raising capital requirements in a less competitive sector in the model, we can look to the non-corporate sector. Here, the impacts can be more significant: for example, raising the capital requirement to 15% results in a 10.9% drop in non-corporate debt. If non-corporate firms comprised a large share of total activity, then, it might be possible to deliver larger aggregate effects. Recall, though, that non-corporate firms in the model face an extremely non-competitive bank sector: conditional on a match, a bank is a monopolist over its set of firms. Thus, the impacts on non-corporate firms I document may be viewed as upper bounds. Another way of reducing competition is raising bank entry costs. This would make the average bank larger both in terms of loan market share and net worth. The former effect might increase exposure to shocks, while the latter decreases it; therefore the total effect is ambiguous ex ante.

**Complementarities** In reality, while many firms specialize in particular forms of external financing (Colla et al. (2013)), many others use multiple forms (Rauh and Sufi (2010)). In my model,

[49] Even though the divertibility parameter $\theta$ is large in both sectors, the managerial capture parameter $\omega$ is quite low; even though managers can divert a large share of profits, they can gain relatively little from it.

bank and bond financing are (imperfect) substitutes, and individual firms use only a single lender. If bank financing helps firms obtain non-bank financing, then any drop in bank lending might induce a complementary drop in non-bank lending, potentially offsetting the substitution I document.[50] This effect is likely to be concentrated among the riskiest corporate sector firms.[51]

**Systemic risk** When lending activity leaves the banking sector in my model, it flows to a sector that is free of externalities: increased loan volume and even loan risk are priced in efficiently in the bond market. In reality, though, some of this activity would flow into the so-called "shadow" banking sector. This sector, while not protected by explicit government guarantees, may yet create the potentially for costly "traditional" bank failures through interconnectedness. While my analysis cannot speak to this notion of systemic risk, it can speak to the nature of substitution. When tightening the capital requirement in my model, total corporate bank debt declines by only about 1%; it is unlikely that the share of that reduction that would flow to the shadow sector would change systemic risk materially. Moreover, if banks were competing with shadow banks for loans in the non-corporate sector, this would dampen the impacts in this sector as well.

# 6 Conclusion

In this paper, I have presented a tractable dynamic framework with heterogeneous banks and firms and aggregate risk to analyze the impacts of changing capital requirements. Motivated by the modern U.S. financial system, corporate borrowers may obtain financing outside the regulated banking sector. The model features (i) endogenous substitution between lenders by firms; (ii) a unique role for banks; and (iii) externalities associated with bank failures, creating a role for bank regulation. There is two-sided moral hazard, financial frictions in banking, and a rich competitive structure within the banking sector and between banks and the bond market. This constellation of forces allows for a rich set of sectoral and aggregate adjustments to changes in capital requirements.

The quantitative model matches key moments regarding the composition of debt across lenders and by firm sector, as well as a series of business cycle facts and micro-level pricing patterns. Given these properties, I use the model to study the long run impacts of increasing bank capital requirements. I find that changing the capital requirement has small effects on top line macroeconomic aggregates and welfare, but potentially sizable effects within specific economic sectors. The welfare of the representative household is maximized at a capital requirement of 9%, slightly above the baseline level of 8%. As the capital requirement is increased, the non-corporate sector faces a credit crunch, while increased competition from the non-bank sector and better-capitalized banks lead to a modest expansion in the corporate sector. The rate of bank failures decreases modestly as the capital requirement is increased.

[50] See, for example, the models of Crouzet (2018) or Xiang (2017).

[51] Another, quite different form of complementarity could come from the labor market: if the most adversely affected non-corporate firms comprise the majority of labor demand, there could be a feedback effect through the labor market. Since there is no frictional labor market in this model, this effect is shut down.

What delivers these results? In the long run, banks respond to a tighter cap on leverage by maintaining larger capital buffers, issuing more equity and cutting dividends on the margin. Even in the short run, this adjustment is not very costly since banks' profitability implies that they can readily increase net worth by retaining earnings. Second, the discipline imposed on banks by the non-bank sector implies that sharp increases in loan rates are not the most profitable way for most banks to adjust to the stricter regulation. This leaves the corporate sector, which can freely substitute into bond financing, relatively unaffected, while the non-corporate sector bears the brunt of the adjustment. Ultimately, then, my analysis shows that the presence of a non-bank lending sector does not dampen the benefits associated with raising capital requirements; rather, it suggests that this sector moderates any ancillary negative side effects.

This paper contributes to the macro-banking literature on capital requirements by examining borrower substitution and banks' rich financing options in an environment with firm and bank heterogeneity. Towards a parsimonious exploration of these core ideas, the model has abstracted from certain realistic elements which might be fruitfully examined in future studies. 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 can be enriched to include levered shadow banks. I leave these and other questions for future research.

**Data availability statement** *The data and code underlying this research are available on Zenodo at https://doi.org/10.5281/zenodo.14872058.*

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