Bank Capital Requirements: A Quantitative Analysis

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Abstract

This paper examines the welfare implications of bank capital requirements in a general equilibrium model in which a dynamic banking sector endogenously determines aggregate growth. Due to government bailouts, banks engage in risk-shifting, thereby depressing investment efficiency; furthermore, they over-lever, causing fragility in the financial sector. Capital regulation can address these distortions and has a first-order effect on both growth and welfare. In the model, the optimal level of minimum Tier 1 capital requirement is 8%, greater than that prescribed by both Basel II and III. Increasing bank capital requirements can produce welfare gains greater than 1% of lifetime consumption.

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1 Introduction

Following the recent financial crisis, a change to bank regulatory capital requirements has become one of the key regulatory reforms under consideration as well as the subject of an extensive academic debate (see Admati, DeMarzo, Hellwig, and Pfleiderer (2010)). There is a strong consensus among policymakers in favor of higher bank capital requirements. The benefit of increased requirements is clear: having more capital helps banks better absorb adverse shocks and thus reduces the probability of financial distress. More capital would also reduce bank risk-taking incentives and thus improve investment efficiency and overall welfare. The banking industry has adamantly pushed back the effort to increase capital requirements however, arguing that an increase in the bank capital requirement could adversely affect bank lending and leads to lower economic growth. For effective policy making, it is thus vital to determine which effect dominates by quantitatively assessing the welfare implications of higher bank capital requirements.

To contribute to the current debate, this paper analyzes the welfare implications of bank equity capital requirements in a model with endogenous growth and a dynamic banking sector. The endogenous growth framework is important because it allows bank regulation to affect the growth rate of the economy. Banks play an important role in financing capital production, which in turn is used to produce final goods. In the model, sustained growth results from capital accumulation (Romer (1986)); therefore, any distortion in bank lending will have an effect on aggregate activities. This paper focuses on the distortions that bank bailouts cause and the role that bank capital requirements play in mitigating these distortions.[1]

To this end, banks in the model economy are taken to be big banks, which entails the assumption that the government bails out banks with a high probability ex-post. This

[1]There are other motivations for regulating banks, for example, to prevent contagious effects of bank failures on other banks or prevent asset fire sale that could cause additional failures. This paper focuses on bailout distortions because I think it is important and has first order effects. The role of bank capital regulation on containing financial contagion and asset fire sale are left for future research.

can be motivated from the recent financial crisis: many large institutions were bailed out through programs such as the Troubled Asset Relief Program (TARP) and the emergency Federal Deposit Insurance Corporation (FDIC) Temporary Liquidity Guarantee Program. This FDIC program guarantees bank debt and business checking accounts, which are not normally covered under the FDIC's deposit insurance. Nonetheless, the fall of Lehman Brothers, Washington Mutual and Wachovia has shown that governments can and do permit big banks to fail. The proposed model captures both dynamics.

The high probability of bailout implies that ex-ante bank depositors expect to be compensated even if banks default, and hence banks do not have to remunerate depositors entirely for bank default risk. Thus deposits are a cheap source of funding for banks. This causes banks to over-lever. Moreover, given the option to default due to limited liability, banks have incentives to risk-shift, lending to risky and less productive firms. This lending practice allows banks to reap the benefits when they succeed but escape costs when they fail. Risk-shifting by bankers has welfare implications because funds are used inefficiently. In addition to prospective government bailouts, other factors that determine bank capital structure in the model are bank default cost and equity issuance cost.

When calibrated to match key moments in the distribution of U.S. banks as well as macroeconomic quantities, the model produces a hump-shape in welfare, with the optimum at an 8% minimum Tier 1 capital requirement. This is 2 percentage points higher than the level of Tier 1 capital ratio recommended by Basel III in 2010, a measure that was adopted by U.S. regulators in July 2013, and 4 percentage points higher than the Basel II requirement. Relative to the 4% Basel II minimum Tier 1 capital ratio, the 8% level improves welfare by 1.1% of lifetime consumption. That is, requiring banks to hold a minimum of 8% in equity capital is equivalent to giving the representative agent with a 4% minimum capital requirement a 1.1% increase in consumption every period. What is more important is that welfare gains remain sizable even at very high levels of capital requirement.

The intuition for the result is as follows. At low levels of bank capital requirements, banks

raise funds from depositors to exploit the subsidy implicit in government bailouts. Banks, therefore, can provide more credit for capital production, which results in more capital being produced, leading in turn to higher growth. However, at low levels of bank capital requirements, because banks have the default option and do not have enough "skin in the game," they engage in risk-shifting, lending to risky-low-productivity firms. Consequently, the average investment productivity in the economy is low and the rate of bank default is elevated, which leads to high capital losses. Therefore, in order to attain high growth, since investment is inefficient, substantial resources are used for capital production, and little is left for consumption. The net effect is lower welfare despite higher growth.

As the minimum capital constraint increases, so does the shadow cost of funding for banks. Moreover, the extent to which banks can exploit the implicit subsidy using deposits reduces, and a larger proportion of banks have to issue equity, for which they have to pay issuance cost. Therefore, more banks exit the economy, aggregate credit is tightened, less capital is produced, and growth is lowered. At the same time, however, bank lower leverage and lower incentive for risk-shifting result in lower default and higher overall capital production productivity and consumption. The effect on increasing productivity and consumption dominates the lowered growth and leads to a graduate increase in welfare, reaching a maximum of 1.1% of lifetime consumption when the capital requirement is at 8%.

As the capital requirement increases above 8%, lower welfare gains result. The reasons are twofold. The first is equity flotation costs. Since banks must pay issuance costs and these are rebated back to households, the private cost of issuing equity is higher than the social cost. Therefore, the funds that are raised are lower than those in a centralized economy. This leads to lower lending, lower capital production, and hence lower growth. The second reason is the presence of the "learning-by-doing" spillover that is inherent in the Romer (1986) endogenous growth model. In this class of models, capital accumulation improves overall final good production productivity, and because this is external to each individual final good producer, decentralized allocations entail under-investment and lower capital accumulation.

Consequently, any policy that further discourages investment lowers welfare. In the current setup, higher bank capital requirements increase the private cost of capital for banks, causing a reduction in lending and thus a lower accumulated stock of capital. This brings the decentralized allocations further away from the first-best allocation and lowers welfare gains.

To the best of my knowledge, the proposed model is the first, in a fully specified dynamic general equilibrium setting, to quantitatively investigate the impact of capital requirements on deterring moral hazard, on financing and hence growth.

1.1 Related Literature

This paper is at the intersection of a large literature on banking and macroeconomics. On the macroeconomic side, this study is related to a burgeoning strand of literature started by Kung and Schmid (2011) that uses endogenous growth models to generate long-run consumption growth risk, a feature that is essential for explaining asset market data (Bansal and Yaron (2004)). Croce, Nguyen, and Schmid (2012) examine the link between fiscal policies and pessimism in the spirit of Hansen and Sargent (2010). Croce, Nguyen, and Schmid (2013) analyze fiscal policy design when there is a tradeoff between short-run stabilization and long-run growth risk. More closely related to the setup in the present paper, Opp (2010) focuses on the role of the financial sector in amplifying shocks in a Schumpeterian growth model.

On the banking side, there are many theoretical studies on moral hazard due to public guarantees. In the context of deposit insurance, Merton (1977) shows that deposit insurance provides banks with a put option, and thus without any regulation banks would find it privately optimal to take on more risk. Furthermore, Mailath and Mester (1994) analyze bank closure policy and show that over a wide region of parameters, "too-big-to-fail" banks arise in equilibrium and can lead to excessive risk-taking. There is also a strand of literature that predicts a reduction in risk-taking following such guarantees. Bailouts raise the charter value for banks because banks then benefit from the lower cost of funding. This induces banks to be more conservative in lending, because they have more to lose in default (Keeley (1990)).

Cordella and Yeyati (2003) and Hakenes and Schnabel (2010) show that the net effect on risk-taking depends on which channel dominates. Consistent with these theoretical predictions, in the present paper banks risk-shift only when their charter values are sufficiently low, and they do not engage in risk-shifting otherwise.

The main instrument used by regulators to restrict bank risk-shifting incentive is minimum capital requirements, and there are many theoretical studies on the effectiveness of this instrument. For example, Hellmann, Murdock, and Stiglitz (2000), Repullo (2004), and Morrison and White (2005) analyze the role of capital in disciplining bank moral hazard. Allen, Carletti, and Marquez (2011) study capital regulation in the case in which credit market competition induces banks to hold capital in excess of the regulatory constraint, a fact that is robust in the data. The authors show that the decentralized solution entails banks' holding a level of capital higher than the regulatory solution. In a similar vein, Mehran and Thakor (2011) argue that there is a positive link between bank capital and bank value because bank capital encourages monitoring; the authors also provide empirical support for their theoretical prediction. Acharya, Mehran, and Thakor (2012) study bank capital requirements when banks face asset substitution by shareholders and rent-seeking by managers, and they analyze the trade-offs of the use of capital regulation to reduce risk-taking vs. allowing debt to discipline managerial rent-seeking. Harris, Opp, and Opp (2013) examine the effectiveness of bank capital requirements in the existence of competition between regulated banks and unregulated investors. They show that when competition is sufficiently strong, bank capital regulation becomes ineffective. The extant literature thus far has not focused on the impact of capital requirements on growth, however; the present paper addresses this gap in the literature.

Empirical studies related to the impact of higher bank capital requirements on lending and costs of capital are limited. Kashyap, Stein, and Hanson (2010) estimate that, for a 10 percentage point increase in the capital ratio, the long-run steady-state weighted average cost of capital for banks increases by 25–45 basis points. Baker and Wurgler (2013) estimate the

impact on average cost of capital of the same policy to be 60–90 basis points. In an interesting study exploiting data on a costly loophole used to bypass the capital requirement, Kisin and Manela (2013) show that a 10 percentage point increase in the capital ratio leads to at most a three basis points increase in banks' cost of capital. These studies shed light on the potential impact of capital requirements on real activities; however, it is difficult to conclude whether such a policy would be beneficial due to the uncertain and potentially nonlinear general equilibrium effects from a substantial increase in the capital ratio. My paper complements these studies in this respect.

Quantitative studies on the welfare impact of bank capital requirements are even more limited. Van den Heuvel (2008) was the first to quantitatively study the welfare cost of bank capital requirements. Using yield spread data, he shows that U.S. regulation at the time was too high due to a reduction in liquidity creation. One crucial assumption in this paper is that bank capital structure is determined by the regulatory constraint. As pointed out by Allen, Carletti, and Marquez (2011), however, this does not seem to be the case in the data. In the context of Van den Heuvel's work, this also means that it is difficult to study the impact of an alternative level of capital requirements. Corbae and D'Erasmo (2012), in partial equilibrium, study capital requirements when there is competition between big and small banks. They find that an increase in the capital requirement leads to a fall in the loan supply and a rise in the interest rate. However, neither Van den Heuvel (2008) nor Corbae and D'Erasmo (2012) address the key concern on the effect of capital regulation on growth, which is at the heart of the current policy debate.

In this paper, banks optimally determine their capital structure by trading off bank default costs, the benefit of implicit guarantees, and equity issuance costs, all while operating in an endogenous growth environment. Thus, the present study complements the literature on understanding the welfare implications of capital regulations. This paper is the first, to the best of my knowledge, to quantitatively investigate the impact of capital requirements on growth and risk-shifting in a fully specified dynamic general equilibrium banking model.

More broadly, my paper is related to the macro literature in which models contain financial intermediaries. He and Krishnamurthy (2012, 2013) study the nonlinear behavior of risk premia and asset volatility in crises in a setup in which financial intermediary capital plays an important role in pricing assets. He and Krishnamurthy (2011) and Brunnermeier and Sannikov (2013) focus on the amplification of shocks, where in equilibrium the economy can enter systemic crisis states. Adrian and Boyarchenko (2012) study leverage cycles in a model in which financial intermediaries can produce capital more efficiently than households and intermediary leverage is restricted by a value-at-risk constraint. They show that this constraint plays an important role in amplifying shocks; moreover, varying the tightness of the value-at-risk constraint produces an inverted U-shape in households' welfare. As the authors pointed out, however, this result depends on the assumption that intermediaries finance themselves only with debt. Moreover, as is common in this literature, Adrian and Boyarchenko's paper relies on heterogeneity in preferences between financial intermediaries and households. This makes it somewhat difficult to analyze welfare effects. In my model, homogeneous households own all productive assets, and welfare is readily comparable between different levels of capital constraint. Importantly, in my model financial intermediaries hold financial assets–giving loans to firms, instead of directly investing in capital projects. This makes it easier to interpret these intermediaries as banks and examine bank capital regulations.

In a different setup, Gertler and Kiyotaki (2013) examine bank instability in a model where households are subject to liquidity shocks, leading to bank runs as in Diamond and Dybvig (1983). Gertler, Kiyotaki, and Queralto (2011) consider a model with financial intermediation in which the intermediaries can issue outside equity as well as short term debt, making intermediary risk exposure an endogenous choice. In a DSGE model with financial intermediaries, as in Holmstrom and Tirole (1997), Meh and Moran (2010) study the role of intermediary capital in the propagation of shocks. Similarly, Angeloni and Faia (2013), using a financial sector as in Diamond and Rajan (2000, 2001), analyze capital regulation and

monetary policy. In Angeloni and Faia's work, growth is *exogenously* determined, however, and it is not clear why banks should be regulated in the first place.

The rest of the paper is organized as follows. Section 2 reviews evidence on bank risk-shifting. Section 3 discusses the model, and Section 4 gives a quantitative assessment of bank capital requirements. Section 5 concludes.

2 Evidence on Bank Risk-Shifting

In the model described in this paper bailouts cause banks to risk-shift; this prediction is well known within existing banking theories and has ample empirical support. As this is a prominent feature of my model, I nonetheless review these evidence here. Gropp, Gruendl, and Guettler (2013) use a natural experiment in the removal of government guarantees for German savings banks; they show that after guarantees are removed, banks reduce credit risk and adjust their liabilities away from risk-sensitive debt instruments. Moreover, their bond yield spreads increase significantly. The authors conclude that public guarantees result in substantial moral hazard effects. Furthermore, Dam and Koetter (2012) use a data set of actual bailouts of German banks from 1995–2006 and show that increases in bailout expectations significantly heighten bank risk-taking.

In a recent study on risk-shifting, Duchin and Sosyura (2013) use data on bank applications for government assistance under the TARP and show that banks make riskier loans and shift investment portfolios toward riskier securities after being approved for government assistance. This is consistent with the moral hazard story, as an approved for assistance through TARP signals government support going forward. In a related study, Black and Hazelwood (2012) compare the risk ratings of commercial loan originations of TARP recipient and non-recipient banks and show that loan orginations risk increases at large TARP-recipient banks. On a related note, Drechsler, Drechsel, Marques-Ibanez, and Schnabl (2013) use a unique data set from the European Central Bank (ECB) and show evidence that during the re-

cent financial crisis, of banks that borrow from the Lender of Last Resort–the ECB in this case–those with lower financial strength borrowed more and pledged increasingly risky collateral. The authors test four different theories and show that risk-shifting by banks is most consistent with this fact.

There is also ample evidence of risk-shifting owing to another form of public guarantee: deposit insurance. Grossman (1992) uses a data set of insured and uninsured thrifts in the 1930s and documents that after several years, insured thrifts engaged in relatively riskier lending activities as measured by the foreclosures-to-assets ratio. Wheelock and Wilson (1995) show that deposit insurance membership increases the probability of bank failure. From cross-country evidence, using differences in the presence and design of deposit insurance schemes, Demirguc-Kunt and Detragiache (2002) find that countries with explicit deposit insurance are more likely to have banking crises. All in all, existing empirical evidence suggests that when there are public guarantees, banks engage in risk-shifting.

3 Model

The model consists of four types of agents: (1) households, who consume and save, (2) final good producers, who produce the consumption good, (3) capital-producing firms, who produce capital, and (4) banks, who raise funds from households and lend to capital-producing firms. I will now describe each of the agents in turn.

3.1 Households

The economy is populated by a measure one of identical households who have CRRA preferences over consumption C_t,

$$U_0 = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \frac{C_t^{1-1/\psi} - 1}{1 - 1/\psi},$$

where ψ is the intertemporal elasticity of substitution and $\beta \in (0,1)$ the subjective discount factor. In every period, households are also endowed with one unit of labor, $L_t = 1$, and since they do not value leisure, they supply labor inelastically. The discount factor can be written as usual:

$$M_{t+1} = \beta \left(\frac{C_{t+1}}{C_t} \right)^{-1/\psi}.$$

Households are owners of capital-producing firms, banks, and final good producers. In addition to equity shares, they hold deposits issued by banks. I assume that they can split their deposits and equity shares equally among all banks, so that the law of large numbers applies and all idiosyncratic risks, as will be specified in subsection 3.3 and 3.4 below, are diversified away. All proceeds are returned to the household at the end of the period.

3.2 Final Good Production

There is a measure one of final good producers. Producer $u \in [0,1]$ has technology

$$y_{ut} = A_t k_{ut}^{\alpha} (K_t l_{ut})^{1-\alpha}, \tag{1}$$

where A_t is total factor of productivity, k_{ut} is producer u's capital, l_{ut} is labor demand, and K_t is the aggregate level of capital, which producer u takes as given. This is a simple way to generate endogenous growth as in Romer (1986) via the "learning-by-doing" externality. Aggregate capital and labor are then simply

$$\int_0^1 k_{ut} du = K_t \tag{2}$$

and

$$\int_0^1 l_{ut} du = L_t = 1. \tag{3}$$

Since all producers function at the same capital-effective labor ratio, aggregate output can be written as

$$Y_t = \int_0^1 y_{ut} du = A_t K_t L_t^{1-\alpha} = A_t K_t. \tag{4}$$

In aggregate, therefore, there is no diminishing return to capital despite diminishing return at the individual final good producer level. This is the source of growth in the model. Capital accumulation by an individual final good producer increases productivity by all other producers through aggregate capital K_t, but since this is taken as external to the producer, in the decentralized allocations there is under-investment. This externality on the production side will have important implication for bank capital regulations.

Let p_t^I be the relative price of capital. The final good producer u chooses investment i_{ut}^d and dividend d_{ut} to maximize shareholders' value

$$v(k_{u,t-1}, K_t, A_t) = \max_{i_{ut}^d, d_{ut}, l_{ut}} d_{ut} + \mathbb{E}_t M_{t+1} v(k_{ut}, K_{t+1}, A_{t+1}), \tag{5}$$

subject to

$$d_{ut} = y_{ut} - W_t l_{ut} - p_t^I \cdot i_{ut}^d - \frac{a}{2}\left(\frac{i_{ut}^d}{k_{u,t-1}}\right)^2 k_{u,t-1} \tag{6}$$

$$k_{ut} = (1-\delta)k_{u,t-1} + i_{ut}^d, \tag{7}$$

where δ is the depreciation rate of capital and W_t the equilibrium wage rate. The last term in (6) captures investment adjustment costs, a standard assumption in the macrofinance literature. Aggregate demand for the capital good is then

$$I_t^d = \int_0^1 i_{ut}^d du = i_{ut}^d,$$

where I am considering the symmetric equilibrium in which all final good producers behave identically. The first-order condition with respect to capital implies that, in the symmetric

equilibrium, the price of capital satisfies the condition

$$p_t^I = A_t \alpha L_t^{1-\alpha} - a\frac{I_t^d}{K_{t-1}} + \mathbb{E}_t M_{t+1}\left[p_{t+1}^I(1-\delta) + \frac{a}{2}\left(\frac{I_{t+1}^d}{K_t}\right)^2 + a\left(\frac{I_{t+1}^d}{K_t}\right)(1-\delta)\right]. \quad (8)$$

In equilibrium, aggregate capital demand must equal aggregate capital supply produced by capital-producing firms. Since in the model financial frictions mainly affect the capital supply, this is the channel through which bank regulations affect the whole economy.

3.3 Capital-Producing Firms

The economy consists of islands indexed by j. One can think of an island as an industry or a state; what is important, as will become clear, is that there is an idiosyncratic shock specific to j that cannot be diversified away. On each island, at the beginning of each period, a large number of infinitesimal capital-producing firms is born. These firms are short-lived.

Each firm is endowed with a project with a required investment of i_t today for production tomorrow. i_t is taken as given by all agents in the economy. Those firms that get financing invest today and then produce capital, settle payments, and exit the economy tomorrow. Those that do not get financing exit the economy immediately. Then new firms are born.

Firms on any island are of two types: *normal firms* and *risky-low-productivity firms*. For the normal firm, investing i_t today produces $z_{j,t+1} \cdot i_t$ units of capital tomorrow, where z_{jt} is an island-specific persistent shock:

$$\log z_{j,t+1} = \rho_z \log z_{jt} + \sigma_z \epsilon_{zj,t+1}, \quad \forall j.$$

As for the risky-low-productivity firm, investing i_t today produces $z_{j,t+1}\epsilon_{jf,t+1} \cdot i_t$ units of capital tomorrow, where $\epsilon_{jf,t+1}$ is specific to firm f in island j. This shock is independent and identically distributed across firms, that is,

$$\log \epsilon_{jft} \sim \mathcal{N}\left(-\mu - \frac{1}{2}\sigma_\epsilon^2, \sigma_\epsilon\right) \quad \forall j, f, t.$$

Therefore, risky-low-productivity firms are both riskier because they are exposed to an additional shock, and on average less productive, $\mu \geq 0$, than normal firms. The technology for both type of firms can be written compactly as

$$z_{j,t+1} \cdot [\chi \epsilon_{jf,t+1} + (1 - \chi)] \cdot i_t,$$

where χ is an indicator function equal to one if the firm is a risky-low-productivity firm and zero if it is a normal firm. To economize on notation, I drop the subscript j where there is no risk of confusion.

To invest, firms must pay a small constant marginal operating cost o. This operating cost is however can be raised within the households that own the firms, that is, for each firm, the internal equity is enough to cover operating cost. As for the funds that must be invested into the firms, i_t, because of unmodeled commitment or moral hazard frictions they cannot borrow directly from other households. They can, however, approach banks for funds because banks have a monitoring technology that solves the moral hazard problem.[2] Since there is a large number of firms on each island, firms behave competitively, and the lending rate R^l is determined by firms' zero profit condition, taking into account the default option and whether firm f is a risky firm:

$$\mathbb{E}_t M_{t+1} \underbrace{\max\{0, p^I_{t+1} z_{t+1}[\chi \epsilon_{f,t+1} + (1 - \chi)] - R^l(\chi, z_t)\}}_{\text{Firm's default option}} \cdot i_t = \underbrace{o \cdot i_t}_{\text{Operating cost}} \tag{9}$$

Recall that p^I_t is the market price of capital. Thus the left hand side of equation (9) is firm f's expected discounted revenue net of loan repayment. The 'max' operator captures the

[2]For example, because the capital-producing firms are short-lived, they cannot commit to paying back their loans. Banks, however, can enforce their claims better than households because of their expertise and thus make lending possible (Diamond and Rajan (2000, 2001)). Another possibility is that firms can invest in bad projects and get private benefits from these bad projects. Because of this moral hazard problem, financing from households is not feasible. Banks however can monitor these firms, and thus financing become possible through banks (Holmstrom and Tirole (1997)). The goal of this paper is to study the quantitative implications of bank capital requirements, and so the emergence of bank is abstracted away.

fact that firm has the option to default on its loan if the proceeds from the sale of capital are not enough to cover the loan repayment. The firm's default option implies that there exists a firm-specific cutoff in terms of the shock tomorrow $\bar{z}_{t+1}(z_t, \chi, \epsilon_{f,t+1})$ such that firm f will default if the productivity z_{t+1} on the island falls below that level.

3.4 Banks

On each island, banks differ in the net cash, denoted by π_t, that they have on hand at the beginning of the period. If not exiting the economy, each bank must choose one firm to finance.[3,4] A bank's revenues realized next period from lending this period are then

$$\hat{\pi}_{t+1}(\chi_t, z_t, z_{t+1}, \epsilon_{f,t+1}) = i_t \Big[R^l(\chi_t, z_t) \cdot \mathbb{1}_{\{z_{t+1} \geq \bar{z}_{t+1}\}} + \underbrace{\eta \cdot p^I_{t+1} z_{t+1} [\chi_t \epsilon_{f,t+1} + (1 - \chi_t)]}_{\text{Liquidated asset value}} \cdot \mathbb{1}_{\{z_{t+1} < \bar{z}_{t+1}\}} \Big], \tag{10}$$

where η is the fraction of capital that could be recovered from the firm if it defaults, and with a slight abuse of notation, where χ_t denotes the bank's choice of the type of firm to finance this period. This also means that there is no asymmetric information, and banks know the type of firms to which they give loans.

If it finances a firm, a bank must spend resources to monitor it. In particular, I assume the monitoring cost is m per unit of investment. One could think of this cost as the intermediation cost of providing credit.

Each bank could finance its loan using a mixture of debt and equity. Let b_t be the amount of deposits outstanding and R^b_t the required deposit rate. Further, let d_t be the net equity

[3] One could think that each bank finances a portfolio of firms, which have a firm-level idiosyncratic shock. By the law of large numbers, the firm-level idiosyncratic risk is diversified away, but because all firms are in the same island, the island-specific shock is not. Therefore, allowing banks to hold a portfolio of firms is equivalent to the current setup. Notice that when a bank wants to risk-shift, it wants exposure to a firm specific shock, and so it is optimal for a bank *not* to diversify this risk away.

[4] Either financing or exiting is equivalent to giving banks the option to not finance any firm, but they have to pay a fixed operating cost that is the same as an entry cost, to be described later. Thus not financing any firm and paying the fixed operating cost is equivalent to exiting the economy today and re-enter next period after paying the entry cost.

issuance. The bank's budget constraint is

$$\underbrace{\hat{\pi}_t - R_t^b b_t}_{\equiv \pi_t} - m \cdot i_t + b_{t+1} = i_t + d_t, \tag{11}$$

where the net cash, π_t, is revenues from lending last period net of current deposit liabilities. The left-hand side of (11) is the source of funding and the right hand-side is the use. In addition to new debt b_{t+1} issued, the bank's resources come from lending last period, net of interest payments on deposits and monitoring costs. Funding is used for financing a firm this period and for paying dividends.

If the bank issues equity, i.e., $d_t < 0$, it has to pay a flotation cost. To better match quantity, as is common in the dynamic corporate literature, I assume that equity issuance costs are proportional to the amount issued (Gomes (2001); Hennessy and Whited (2005, 2007); Gomes and Schmid (2010b)). In particular,

$$\Phi(d_t) = -\phi \cdot d_t \mathbb{1}_{\{d_t < 0\}}. \tag{12}$$

The indicator function means that this cost is only applied when the bank issues equity. Distributions to bank shareholders are then just the equity payout net of issuance costs:

$$d_t - \Phi(d_t). \tag{13}$$

Bank equity valuation. Bank equity value is defined as the discounted sum of all future distributions. If the prospect of operating is sufficiently bad, equity holders will choose to close down the bank, i.e., the bank exits the economy. Conditional on the bank exiting the economy, there are two distinct cases. The first is when lending revenue is not enough to cover deposit liabilities. In this case, the bank will stop servicing its deposits and exit; that is, the bank defaults. In the second case, the bank's revenue is greater than deposit liabilities, but economic prospects are sufficiently low that it is optimal for the bank to close down and

pay out its residual cash after servicing its depositors. The value of the bank upon exit is then $V_{xt} = \max\{0, \pi_t\}$. The equity value of the bank is thus the solution to the problem

$$V_t(z_t, \pi_t) = \max\{V_{xt}, \max_{b_{t+1}, \chi_t, d_t} d_t - \Phi(d_t) + \mathbb{E}_t M_{t+1} V_{t+1}(z_{t+1}, \pi_{t+1})\} \tag{14}$$

subject to the loan demand schedule (9), the budget constraint (11), and the minimum bank equity capital requirement

$$\frac{\pi_t - m \cdot i_t - d_t}{i_t} \geq \bar{e}, \tag{15}$$

where the net cash next period is

$$\pi_{t+1} = \hat{\pi}_{t+1}(\chi_t, z_t, z_{t+1}, \epsilon_{f,t+1}) - R^b_{t+1} b_{t+1}. \tag{16}$$

The denominator in (15) is the loan given to the firm, and that represents the bank's total assets. In the numerator, the first two terms are retained earnings and the last term is the dividend payout (d_t is positive) or the equity raised (d_t negative); thus, the numerator represents the total equity that the bank uses to finance its assets. The minimum capital requirement imposes that at least a fraction $\bar{e}$ of the bank assets must be financed by the bank equity capital.

Bank deposit valuation. When a bank decides to stop servicing its deposits, depositors are bailed out with probability λ. To keep the analysis focus, bailouts are assumed to be financed using a lump-sum tax, so that no additional distortion is introduced. If not bailed out, depositors recover a fraction θ of the bank's revenues.[5] The market price of the bank

[5]There are various ways to generalized this model to capture other aspects of bank capital regulation. For example, the probability of bailout λ could be a function of the number of failed banks. This captures the phenomenon of too-many-to-fail (Acharya and Yorulmazer (2007)). The recovery parameter θ could also be a *decreasing* function of the number of failed banks; this captures asset fire sale externality. The bank capital requirement is then also a device to contain fire sale externality.

deposits satisfies the condition

$$b_{t+1} = \mathbb{E}_t M_{t+1} \left[\overbrace{R^b_{t+1} b_{t+1} \cdot \mathbb{1}_{\{V_{t+1}>0\}}}^{\text{Bank does not default}} + \overbrace{\lambda R^b_{t+1} b_{t+1} \cdot \mathbb{1}_{\{V_{t+1}=0\}}}^{\text{Bank defaults–bailed out}} + \underbrace{(1-\lambda)\theta \hat{\pi}_{t+1} \cdot \mathbb{1}_{\{V_{t+1}=0\}}}_{\text{Bank defaults–not bailed out}} \right]. \tag{17}$$

Because of the probability of bailout, the bank does not have to compensate depositors fully for the risk that it undertakes. Moreover since the bank has the option to default when its loan goes bad, the bailout creates incentives for the bank to finance risky-low-productivity firms. This is the typical risk-shifting that has been highlighted in the theoretical banking literature discussed in sections 1.1 and 2.

Entry and exit. Every period, banks enter and exit the economy. As discussed earlier, banks exit when the prospect of operating is sufficiently low, that is, when

$$V_t = V_{xt}.$$

Each period a mass of potential new banks arrives in the economy. Entering entails a setup cost that is proportional to asset size $e \cdot i_t$. Since in this model growth is endogenous, all quantities, including the equity value of the bank, grow at the same rate. The entry cost is modeled proportional to investment to make sure it will not vanish in the long run relative to trend and hence will stay relevant. The potential new bank observes the aggregate state of the economy, but before knowing what island it will be on, it has to pay the setup cost. Once the setup cost is paid, the potential new bank draws the initial shock from the stationary distribution of z_t. Thus, entry occurs if and only if

$$e \cdot i_t \leq \mathbb{E}_z V_t(z_t, \pi_t = 0), \tag{18}$$

where the expectation is taken with respect to the long-run distribution of z_t. The free-entry condition (18) holds with equality when entry is positive.

Distribution of banks. The behavior of each bank is completely characterized by its individual state (z_t, π_t). We can thus summarize the aggregate distribution of banks with a measure defined over this state space. Let $\Gamma(z_t, \pi_t)$ denote the mass of banks with state (z_t, π_t). The law of motion for the measure of banks is given by

$$\Gamma_{t+1}(z_{t+1}, \pi_{t+1}) = T((z_{t+1}, \pi_{t+1})|(z_t, \pi_t)) \left[\Gamma_t(z_t, \pi_t) + B_t(z_t, \pi_t = 0) + E_t(z_t, \pi_t = 0)\right]. \quad (19)$$

Here B_t is the mass of banks that defaults and gets bailed out. They continue to operate with zero net cash. E_t is the measure of new banks, and they enter with no cash. Moreover, for any set $\Theta_{t+1} \subset Z \times \Pi$, the space of possible combination of (z, π), $T(\Theta_{t+1}|(z_t, \pi_t))$ the transition function is defined as

$$T(\Theta_{t+1}|(z_t, \pi_t)) = \int_Z \int_\Omega \mathbb{1}_{\{(z_{t+1}, \pi_{t+1}) \in \Theta_{t+1}|\epsilon_{t+1}\}} \mathbb{1}_{\{V_t > V_{xt}\}} dP(\epsilon_{t+1}) dQ(z_{t+1}|z_t), \quad (20)$$

where Ω is the state space for ϵ, the additional risk exposure for the risky-low-productivity firm. The first indicator is one if given ϵ_{t+1}, the pair (z_{t+1}, π_{t+1}) belongs to Θ_{t+1}, and zero otherwise. The second indicator function takes into account the bank's endogenous exit decision. Q is the transition function for the exogenous shock z, and P is the cumulative distribution function of the ϵ shock.

Bank capital structure and risk-shifting. In additional to the bank's charter value, which is endogenous in the model, bank capital structure is determined by three forces: the equity issuance cost, the bailout probability, and the bank bankruptcy cost. Fig. 1 shows how risk-shifting is manifested in the model and how banks finance their loans when they risk-shift. This figure plots the bank's policy functions on a particular island, where

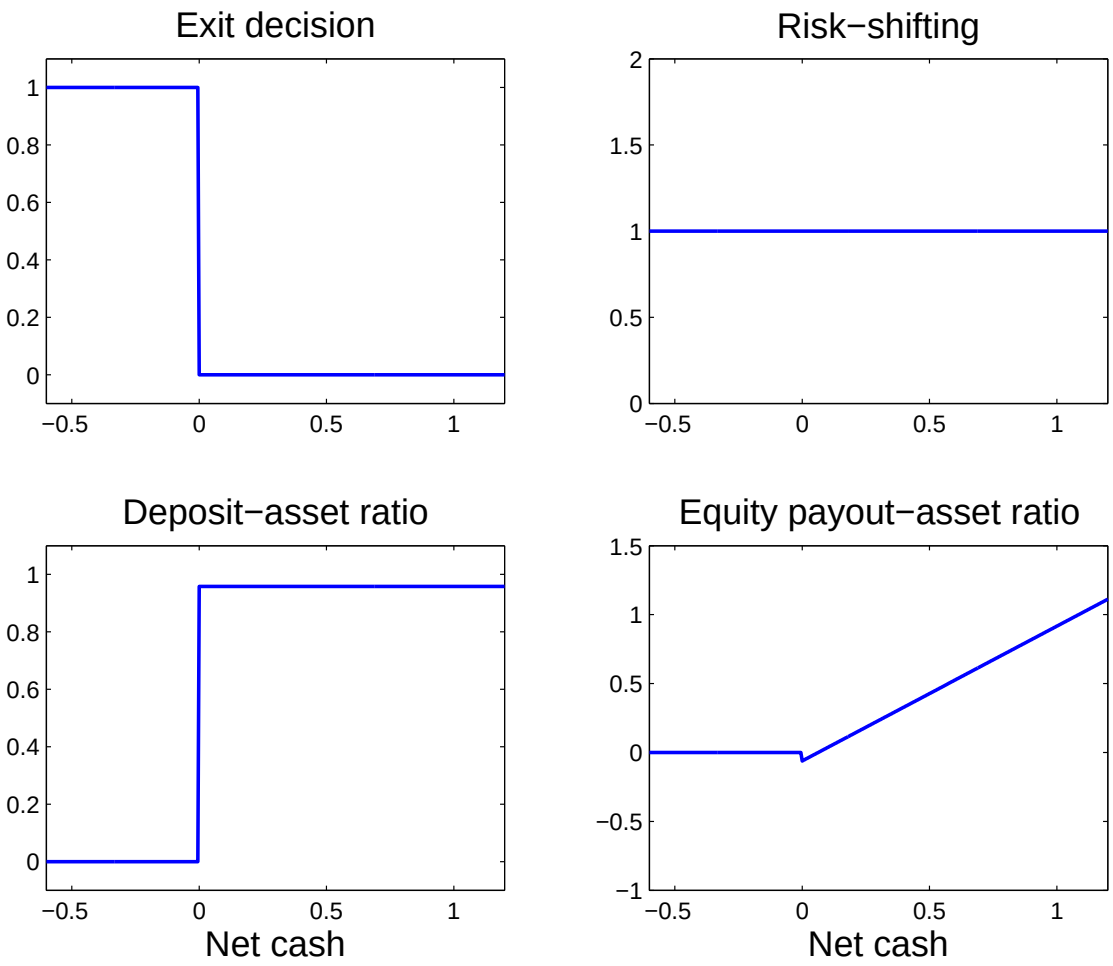


Fig. 1: Policy functions: risk-shifting

Notes – This figure shows a bank's policy functions, on an island where banks risk-shift, as functions of a bank's net cash position. The policy functions are calculated under the benchmark calibration discussed in subsection 4.2.

island-specific productivity is low. Because of low productivity, the bank's charter value is sufficiently low, and this leads all banks on the island to engage in risk-shifting (top right panel). If they do not exit (when the exit decision is zero in the top left panel of Fig. 1), they lever up as much as they can, reaching the minimum capital constraint (bottom left panel), and pay out all their cash as dividends (bottom right panel). This is intuitive. Because banks have the option to default, if they want to risk-shift, they do not want to put in any of their own funds, so that if they succeed they can reap the benefit, whereas if they fail they will lose the minimum amount of their own equity capital. This is where one can see

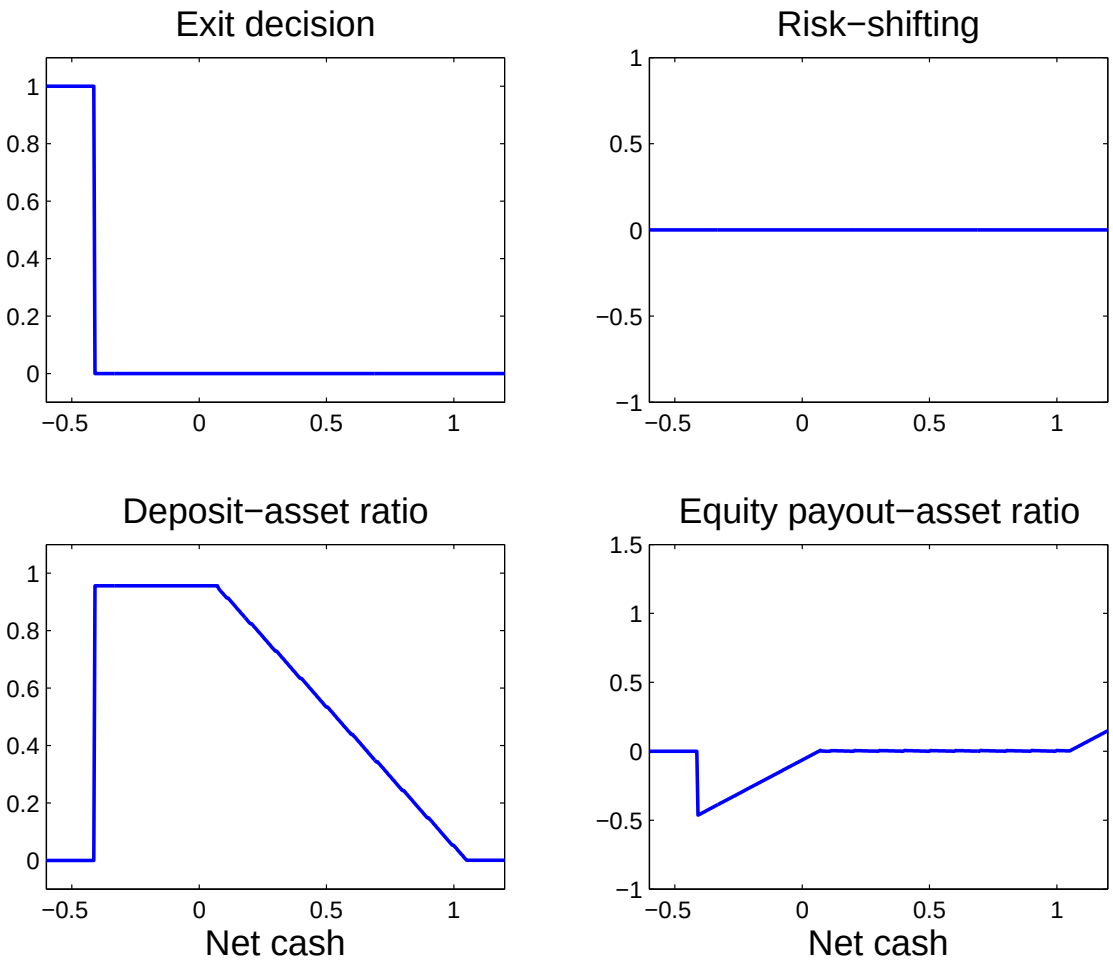


Fig. 2: Policy functions: no risk-shifting

Notes – This figure shows bank's policy functions, on an island where banks do not risk-shift, as functions of bank's net cash position. The policy functions are calculated under the benchmark calibration discussed in subsection 4.2.

how minimum capital requirements could curb the banks' risk-shifting incentives. Imposing greater capital requirements makes banks internalize the downside of risky lending, since they stand to lose more in the event that their loans default. Therefore, capital regulations induce banks to be more conservative in their lending.

On the island where productivity is high, the charter value of banks is high, and therefore they do not have the incentive to risk-shift (top left panel, Fig. 2). On this island, the Myers and Majluf (1984) pecking-order theory of capital structure holds for banks. Banks use internal funds if they have any (equity payout is zero, bottom right panel of Fig. 2), then

issue deposits, and only issue equity as a last resort (equity payout is negative), when the minimum capital constraint binds them. When internal funds are more than enough to finance loans, banks issue dividends. Bank capital structure in this model is thus rich due to heterogeneity in investment opportunities, captured by the island-specific shocks that banks face on different islands.

3.5 Aggregation

Aggregate capital produced can be computed from the following expression:

$$I^s_{t+1} = i_t \int\int z_{t+1}[\chi_t \epsilon_{f,t+1} + (1-\chi_t)] \left[\begin{array}{r} \text{Firm defaults–Bank not} \\ \mathbb{1}_{\{z_{t+1} \geq \bar{z}_{t+1}\}} + \eta \overbrace{\mathbb{1}_{\{z_{t+1} < \bar{z}_{t+1}\}} \mathbb{1}_{\{V_{t+1} > 0\}}}^{} \\ +\eta(\lambda + (1-\lambda)\theta) \underbrace{\mathbb{1}_{\{z_{t+1} < \bar{z}_{t+1}\}} \mathbb{1}_{\{V_{t+1} = 0\}}}_{\text{Both default}} \end{array} \right] \times dP(\epsilon_{t+1} | z_{t+1}, \pi_{t+1}) d\Gamma_{t+1} \tag{21}$$

This aggregation takes into account shocks that firms get next period and the losses due to firms defaulting, banks defaulting, and government bailouts.

In equilibrium, aggregate savings S_t must satisfy

$$S_t = (1 + o + m) i_t \int d\Gamma_t.$$

That is, aggregate savings must equal total lending plus operating costs invested in capital-producing firms by their owners and total costs of financial intermediation. Finally, the aggregate resource constraint is

$$C_t = Y_t - S_t - E_t e \cdot i_t. \tag{22}$$

Recall that E_t is the measure of new banks and $e \cdot i_t$ is entry cost. Notice that unlike in the dynamic corporate finance literature, equity issuance costs are rebated to the households.

Therefore, bank equity regulations will not increase the deadweight loss due to equity issuance costs. This assumption is made to isolate the welfare effect of private incentives in bank equity issuance from any possible social cost due to deadweight losses.

3.6 Equilibrium growth

The aggregate capital accumulation in the model reads

$$K_t = (1-\delta)K_{t-1} + I_t^d.$$

Capital market clearing implies that $I_t^d = I_t^s$; moreover, from (4), growth in equilibrium is

$$\frac{Y_{t+1}}{Y_t} = \frac{A_{t+1}}{A_t}\frac{K_{t+1}}{K_t}.$$

Thus, growth in the model comes from either growth in TFP or growth in capital. When TFP is stationary, as it is in the current setup, economic growth is endogenously determined by capital accumulation. Furthermore, since banks play a crucial role in the financing of investment, regulatory capital requirements will affect growth. The goal of the next section is to quantify the overall effect.

4 Quantitative Assessment

4.1 Regulation and bank data

Regulation. In July 2013, the Federal Reserve Board approved the final rules to implement in the United States bank capital regulations proposed by the Basel Committee on Banking Supervision known as Basel III.[6] These rules include, among other requirements, an increase in the Tier 1 minimum capital requirement from 4% to 6% for all banks. In this paper,

[6]For details, see http://www.federalreserve.gov/newsevents/press/bcreg/20130702a.htm

loans to capital-producing firms are best matched to commercial and industrial loans in the data, and it is natural to interpret capital in the model as Tier 1 capital since these are all common equity and retained earnings. Hence I will calibrate the model to previous regulation, i.e. 4%, to best match macro quantities as well as bank data counterparts from the Reports of Condition and Income, commonly known as the Call Reports and consider welfare implications of different levels of capital requirements relative to this benchmark.

Bank data. Data for banks comes from Call Reports 1984Q1-2010Q4, the FDIC failed bank list and the Federal Reserve Bank of Chicago Mergers and Acquisitions database. Consistent time series are constructed as is standard in the literature (Kashyap and Stein (2000); den Haan, Sumner, and Yamashiro (2007); Corbae and D'Erasmo (2012)). See Appendix A for details. Banks in the model are mapped to big banks in the data, and since it is not clear what the cutoff in size should be, I report statistics for different percentiles in terms of bank total assets. Bank size is not determined in the model; thus, for consistency, failure and exit in the data are calculated not in terms of frequencies but in terms of total bank assets. It is important to note that, in the model, the bank stops servicing its deposits and then depositors get bailed out. However, in the data, in many cases, banks get bailed out before they become insolvent.[7] These bailouts are not recorded in the data set that I use. Therefore, to give the model the best chance of matching bank failure rate data, failure rate is calculated as a fraction total assets of banks that defaulted and did not get bailed out (banks that were not assisted by the FDIC) to total assets of all banks.

4.2 Calibration

One period is a quarter. In the model, all quantities grow at the same rate, so to preserve balanced growth, capital-producing firms' investment size, i_t, must grow at this same rate.

[7]During a private interview with the Financial Crisis Inquiry Commission, Federal Reserve Chairman Ben Bernanke said "out of maybe ... 13 of the most important financial institutions in the United States, 12 were at risk of failure within a period of a week or two." Moreover, many banks that were approved for government assistance through TARP could have become insolvent.

Table 1: Benchmark Calibration

Description	Symbol	Value	Source/Target
TFP level	A	0.11	Match consumption growth
Income share of capital	α	0.45	Cooley and Prescott (1995)
Subjective discount factor	β	0.987	Cooley and Prescott (1995)
Capital depreciation rate	δ	0.025	Jermann and Quadrini (2012)
Intertemporal elasticity of substitution	ψ	1.1	Bansal, Kiku, and Yaron (2013)
Loan recovery parameter	η	0.8	Gomes and Schmid (2010b)
Investment adjustment cost	a	5	Gilchrist and Himmelberg (1995)
Monitoring cost	m	0.02	Philippon (2012)
Bank deposit recovery parameter	θ	0.7	James (1991)
Equity issuance cost	ϕ	0.025	Gomes (2001)
Probability of bailout	λ	0.9	Koetter and Noth (2012)
Firm's operating cost	o	0.023	Average return on loan
Standard deviation of ϵ	σ_ϵ	0.363	x-std return on loan
Bank entry cost	e	0.06	Exit rate
Reduction in productivity of risky firm	μ	0.02	Average net interest margin
Persistence of island specific shock	ρ_z	0.95	x-std net interest margin
Volatility of island specific shock	σ_z	0.011	Failure rate

Notes – This table reports the benchmark quarterly calibration of the model. See subsection 4.2 for detail discussion.

I assume that this investment size is equal to one relative to trend, that is $i_t = K_t$. In this paper, I consider the case where there is no aggregate uncertainty, so A_t is constant and chosen to match consumption growth. The effect of aggregate uncertainty is left for future work. α, β, δ and η are set to standard values in the dynamic corporate literature as well as values traditionally used in macroeconomics. The coefficient on the quadratic adjustment cost, a, is 5, based on a study by Gilchrist and Himmelberg (1995). The intertemporal elasticity of substitution is calibrated according to the long-run risk literature, in particular, it takes a value of 1.1 (Bansal and Yaron (2004); Bansal, Kiku, and Yaron (2013)). θ is set consistent with a study by James (1991), who documented that upon default the average loss on bank assets is about 30 percent. The marginal equity issuance cost ϕ is chosen similarly to Gomes (2001), Hennessy and Whited (2005) and Gomes and Schmid (2010a). The monitoring cost m is set at .02 based on a study by Philippon (2012) who estimated that the intermediation cost is about two percent of outstanding assets. The probability of bailout

λ is set at .9 consistent with a study by Koetter and Noth (2012) who estimated the bailout expectations for U.S. banks to be between 90 to 93 percent. In a data set of German banks during the period 1995-2006, Dam and Koetter (2012) documented that bailout frequency is about 76.4 percent. In this paper, banks are mapped to big banks in the data, so one would expect the bailout expectation to be higher.

This left us with six parameters: o, e, ρ_z, σ_z, σ_ϵ and μ. Since there is not much guidance on these parameters, they are chosen to best match six moments in the cross-section of U.S. banks distribution. The final calibration is summarized in Table 1.

Table 2 reports the main statistics given the benchmark minimum Tier 1 capital requirements of 4%. All cross-section moments are calculated from the stationary distribution of banks. The model does a reasonable job describing macro quantities as well as key cross-sectional moments of the U.S. banking industry. The model has a hard time matching exit rate however. One reason for this is that in the model, if banks want to exit they can just walk away with no cost. However, in the data, banks are big banks and so liquidating the whole bank is very costly. Therefore, outside options for banks in reality are much lower than in the model, and so then is exit. Importantly however the model does a good job at matching bank capital structure. Notice that the leverage ratio (the ratio of Tier 1 capital over total assets) and Tier 1 capital ratio (the ratio of Tier 1 capital over risk-weighted assets) are the same in the model, whereas in the data they are different. In the benchmark calibration, more than 4% of banks risk-shift in equilibrium.

4.3 Welfare implications

Let c_t be the consumption-capital ratio. That is,

$$c_t = \frac{C_t}{K_{t-1}}.$$

Table 2: Main Statistics

Macro moments			Data	Model ($\bar{e} = .04$)
		Δc	0.49	0.49
		c/y	0.76	0.69
Bank moments		Data		Model ($\bar{e} = .04$)
	Top 1%	Top 5%	Top 10%	
Targeted moments				
Return on loan				
mean	4.33	4.63	4.92	4.01
x-std	2.95	3.51	3.99	5.23
Net interest margin				
mean	2.89	3.18	3.43	1.95
x-std	3.05	3.55	4.03	6.09
Failure	0.33	0.29	0.28	1.07
Exit rate	1.02	1.17	1.20	4.27
Other moments				
Net charge-off rate				
mean	2.70	0.93	0.76	2.86
x-std	17.94	13.74	11.00	10.09
Fraction risk-shifting				4.14
Leverage ratio	7.74	8.29	8.51	11.63
Tier 1 capital ratio	10.25	12.18	12.62	11.63
Number of banks	113	564	1129	

Source: Bank data comes from Call Reports 1984-2010. Top x% column indicates statistics calculated from the top x% banks in term of total assets. 'mean' is the time-series average of cross-sectional, and 'x-std' is the time-series average of cross-sectional standard deviation. Macro data is from BEA 1947-2010. Output is defined as consumption plus investment. All figures are in percent, except for consumption-output ratio. For more details on data construction, see Appendix A.

In the stationary equilibrium with no aggregate uncertainty in consideration, the consumption-capital ratio and the growth rate are constant, so that $c_t = c$. Then starting from any initial level of aggregate capital K_0, the level of consumption is

$$C_t = c_t K_{t-1} = c \cdot \Delta k^{t-1} \cdot K_0, \tag{23}$$

where Δk denotes K_t/K_{t-1}. Thus, higher consumption could come from a higher growth (Δk) or a higher initial level of consumption ($c \cdot K_0$). Therefore, welfare is not only a function

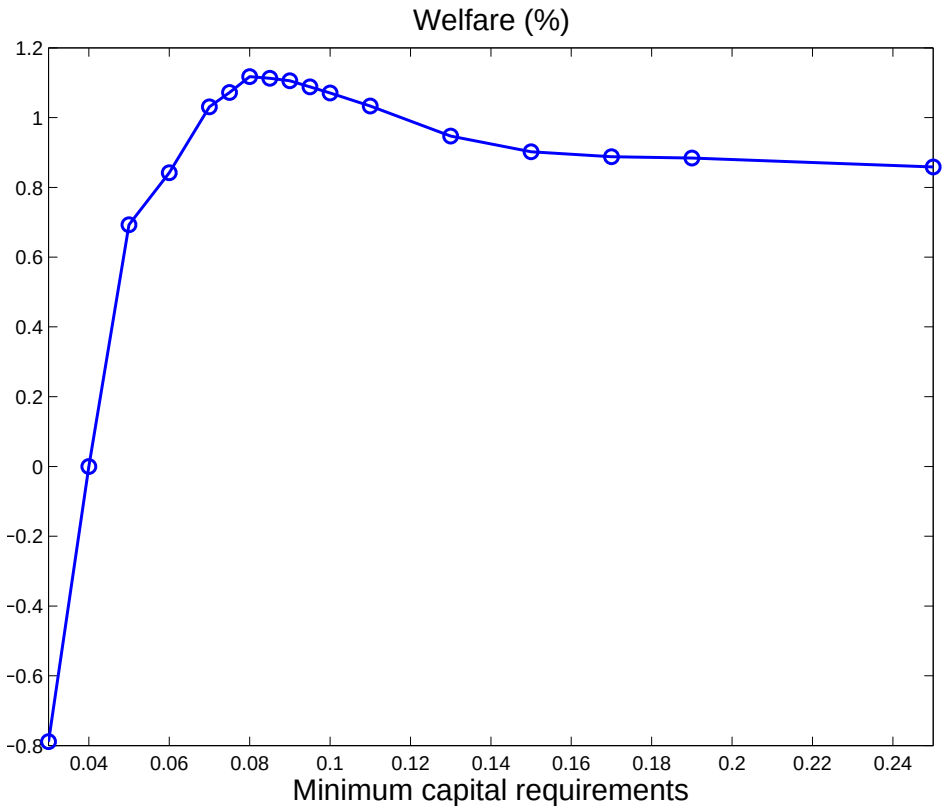


Fig. 3: Welfare benefits

Notes – This figure shows the welfare result as a function of the minimum capital requirement $\bar{e}$ relative to the benchmark calibration with $\bar{e} = .04$. Welfare is expressed in lifetime consumption units. All other parameters are calibrated as in Table 1. The x-axis indicates different levels of the minimum capital requirement.

of growth but also depends on the initial level of consumption. Bank equity capital regulation ultimately alters both the consumption-capital ratio and growth.

Fig. 3 depicts welfare as a function of different levels of minimum capital requirements but with the same initial level of capital K_0. Relative to Basel II, which requires 4% of Tier 1 capital, welfare peaks at a minimum capital requirement of 8%, and the welfare gains reach 1.1 percent of lifetime consumption. What is more important is that welfare benefits remain sizable at very high levels of minimum capital requirement, consistent with analysis by Admati, DeMarzo, Hellwig, and Pfleiderer (2010) and Admati and Hellwig (2013). From a policy perspective, erring on the side of high requirements is safe in the context of this

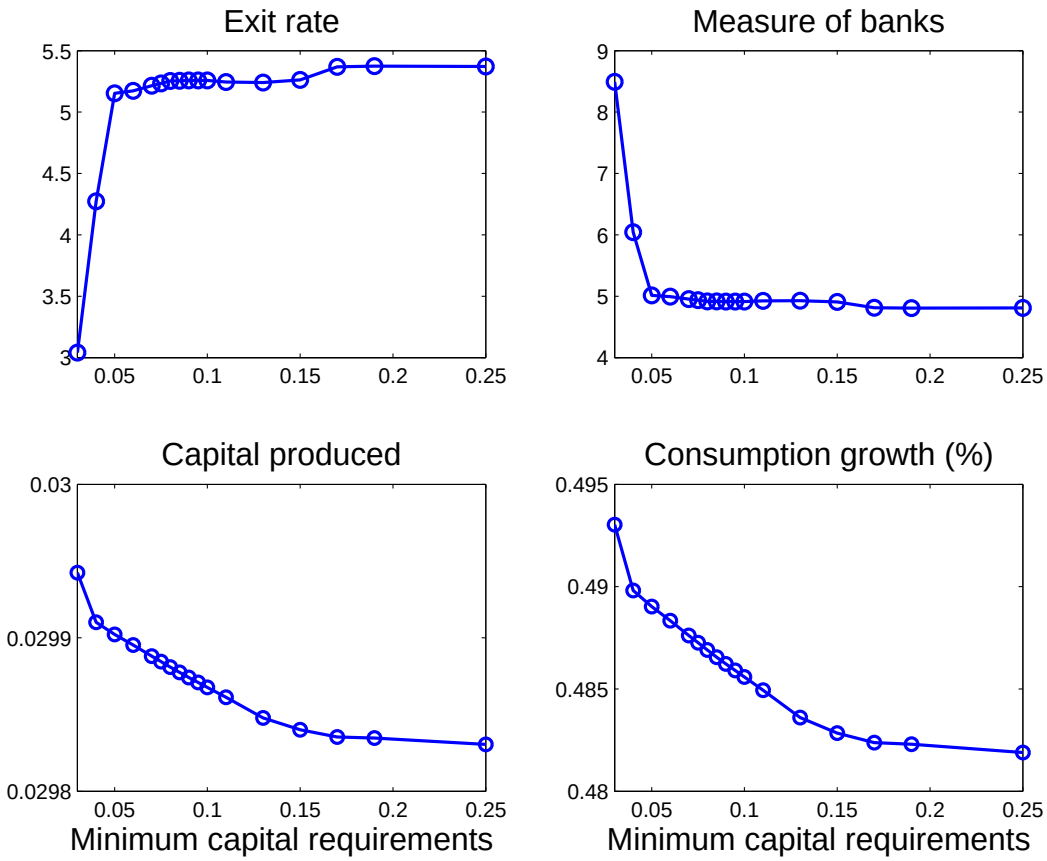


Fig. 4: Consumption growth and distribution of banks

Notes – This figure shows exit rate, the measure of banks, capital produced and consumption growth as a function of the minimum capital requirement $\bar{e}$. All other parameters are calibrated as in Table 1. The x-axis indicates different levels of the minimum capital requirement.

model.

The intuition for the result is as follows. At low levels of the bank equity capital requirements, banks raise funds from depositors to exploit the subsidy implicit in government bailouts. Banks, therefore, can provide more credit to capital-producing firms, which results in more capital being produced (bottom left panel of Fig. 4). More capital produced means that growth is higher (bottom right panel of Fig. 4). Higher growth normally would promote welfare. However, as is clear from equation (23), growth is not the whole story; the starting point of growth is no less important. At low levels of the bank equity capital requirements, because banks have the default option and do not have enough "skin in the game," they

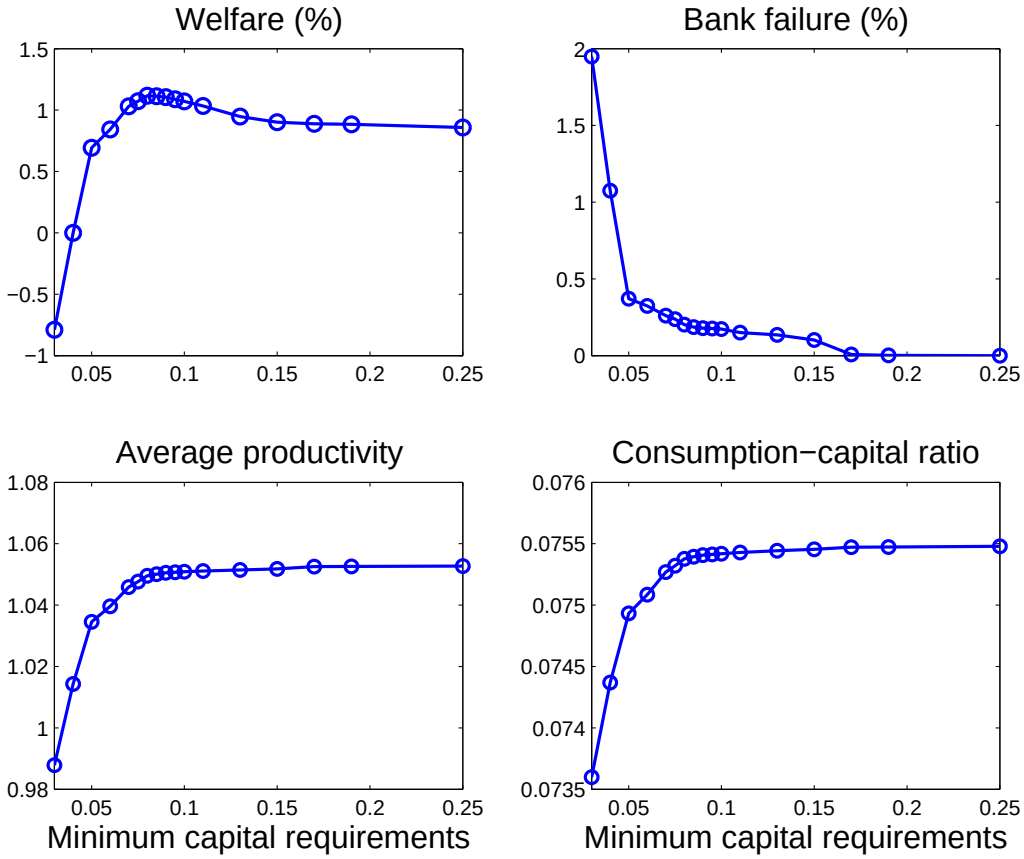


Fig. 5: Welfare benefits, consumption and productivity

Notes – This figure shows the welfare result as a function of the minimum capital requirement $\bar{e}$ relative to the benchmark calibration with $\bar{e} = .04$. The welfare figure is reproduced here for ease of references. All other parameters are calibrated as in Table 1. The x-axis indicates different levels of the minimum capital requirement.

engage in risk-shifting, lending to risky-low-productivity firms. As a result, not only is bank bankruptcy high (top right panel, Fig. 5), which leads to high capital losses, average productivity is also low (top left panel of Fig. 5). Since investment is inefficient, to attain high growth, substantial resources are used for capital production and too few resources are left for consumption (bottom right panel, Fig. 5). The net effect is lower welfare.

As the minimum capital constraint rises, the shadow cost of funds for banks becomes higher. More banks exit because now *private* bank profitability is low (top left panel, Fig. 4). As a result, the total measure of banks is now lower (top right panel, Fig. 4). Consequently,

aggregate credit supply tightens, less capital is produced, and growth is lower. At the same time, however, banks' incentive for risk-shifting is also lower. Moreover, mandating lower leverage through high capital requirements leads to lower bankruptcy rates (top right panel, Fig. 5) and hence less capital is lost due to default. The overall effect brings about higher capital production productivity (bottom left panel of Fig. 5) and higher consumption (bottom right panel, Fig. 5). This leads to an increase in welfare, which peaks at 1.1 percent of lifetime consumption when the capital requirement is at 8%.

There are two reasons why requiring minimum equity capital higher than 8% leads to lower welfare gains. The first is the equity flotation cost. Because banks must pay issuance costs and since these costs are rebated back to households, the private cost of issuing equity is higher than the social cost. Therefore, the funds that raised are lower than those in a centralized economy. This leads to lower lending, lower capital production and hence lower growth. The second reason is because of the presence of the "learning-by-doing" spillover that is inherent in the Romer (1986) endogenous growth model. In this class of models, capital accumulation improves over all final good production productivity and because this is external to each individual final good producer, decentralized allocations entail under-investment and low capital accumulation. In the current setup, higher bank capital requirements increases the cost of capital for banks, causing a reduction in lending leading to low capital production and hence a lower accumulated capital stock. This brings the decentralized allocations further away from the first-best allocation, and lowers welfare gains as seen in Fig. 3.

4.4 Sensitivity Analysis

Role of probability of bailout λ. Fig. 6 plots the welfare analysis for a higher level of bailout probability, increasing from 0.9 in the benchmark calibration to 0.95. As expected, the welfare gain increases at the optimal level of capital requirement from 1.1% to 1.8% of lifetime consumption, and the optimal minimum capital requirement increases from 8% to 9%. This is intuitive since the likelihood of bailout is the source of distortions. The more

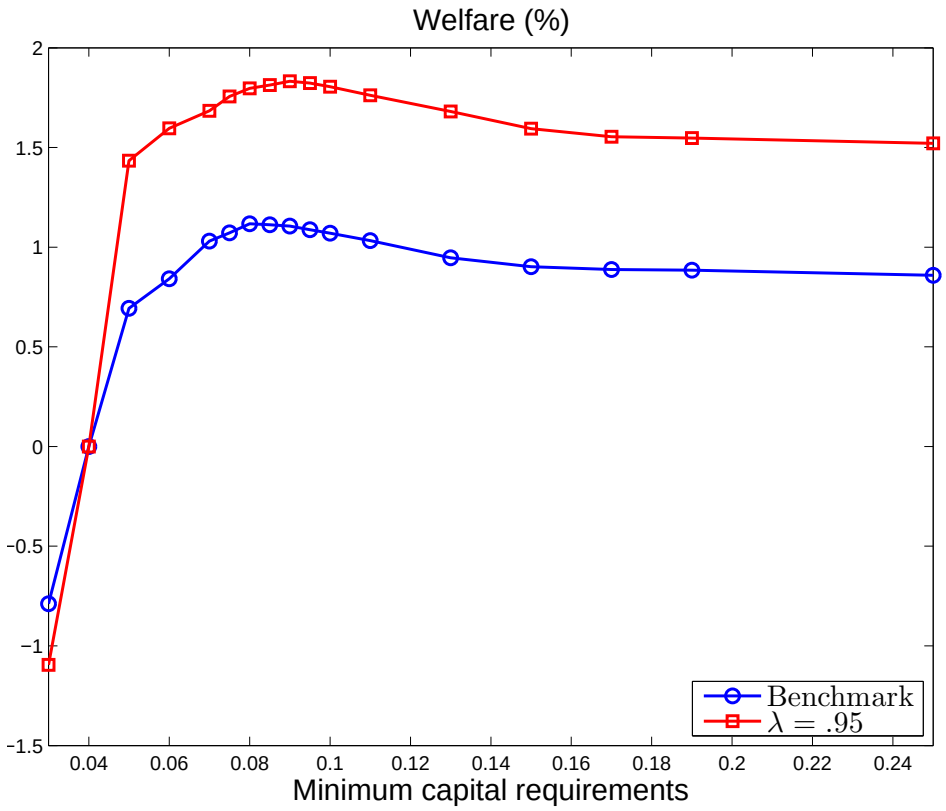


Fig. 6: Role of probability of bailout λ

Notes – This figure shows the welfare result as a function of the minimum capital requirement $\bar{e}$ relative to the benchmark calibration with $\bar{e} = .04$. Welfare is expressed in lifetime consumption units. The blue-circle line is welfare in the benchmark case ($\lambda = .9$), and the red-square line is for the case with bailout probability $\lambda = .95$. All other parameters are as calibrated in Table 1. The x-axis indicates different levels of the minimum capital requirement.

likely a bailout is, the more severe these distortions are, and so correcting these distortions is more beneficial. Not only are welfare gains higher, the optimal level of the minimum capital requirement is also higher. This is because the social cost of high bank capital remains unchanged but the benefit of correcting distortions is now higher.

Role of equity issuance cost ϕ. Fig. 7 compares welfare results when there is no equity issuance cost with the benchmark calibration. Not surprisingly the welfare gains are higher in the case where equity issuance is costless. The result comes from the fact that now the cost of funds for banks is lower, and as a consequence, relative to the benchmark case, more

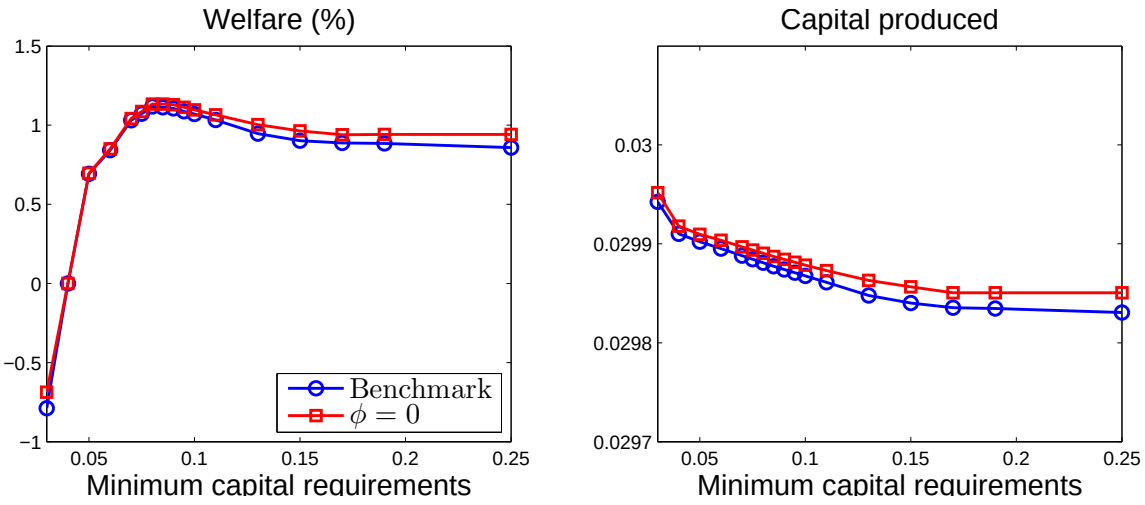


Fig. 7: Role of equity issuance cost ϕ

Notes – This figure shows the welfare result as a function of the minimum capital requirement $\bar{e}$ relative to the benchmark calibration with $\bar{e} = .04$. Welfare is expressed in lifetime consumption units. The blue-circle line is welfare in the benchmark case ($\phi = .025$), and the red-square line is for the case with no issuance cost $\phi = 0$. All other parameters are as calibrated in Table 1. The x-axis indicates different levels of the minimum capital requirement.

funds are raised, more investment is undertaken, and more capital is produced (right panel, Fig. 7).

What is more interesting is that there is still a hump-shape in welfare as one varies the minimum capital requirement $\bar{e}$. As discuss in subsection 4.3, the hump-shape comes from not only the issuance cost but also the under-investment in the decentralized allocations. As more equity capital is required, banks can not exploit the implicit subsidy using deposits and have to use a relatively more expensive form of funds from a *private* perspective; therefore, equilibrium credit supply is lower, resulting in lower capital produced. Overall high capital requirements still lead to lower welfare gains.

Role of productivity loss μ. Fig. 8 depicts welfare results for a lower μ at .01 instead of .02 as in the benchmark case. Recall that μ is the average percentage loss in productivity when a bank finances a risky-low-productivity firm. A lower μ affects equilibrium outcome in two ways. On the one hand, lower μ leads to lower productivity loss and makes investment

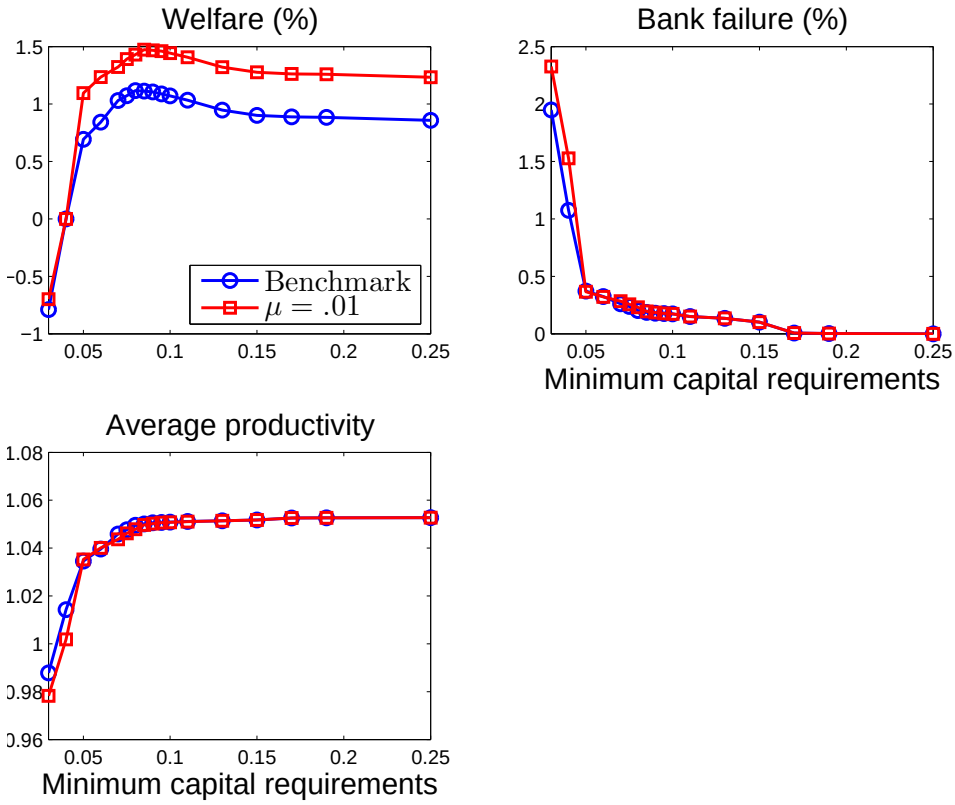


Fig. 8: Role of productivity loss due to risk-shifting μ

Notes – This figure shows the welfare result as a function of the minimum capital requirement $\bar{e}$ relative to the benchmark calibration with $\bar{e} = .04$. Welfare is expressed in lifetime consumption units. The blue-circle line is welfare in the benchmark case ($\mu = .02$), and the red-square line is for the case with $\mu = .01$. All other parameters are as calibrated in Table 1. The x-axis indicates different levels of minimum capital requirement.

more efficient. This tends to improve welfare.

On the other hand, lower μ encourages more banks to risk-shift, because now the private cost of risk-shifting is lower due to a *higher* productivity in risky-low-productivity firms relative to the benchmark calibration. More risk-shifting by banks implies that more banks will default relative to the benchmark (top right panel, Fig. 8). The net result is a reduction in the average investment productivity (bottom panel). Hence, welfare is higher despite lower productivity loss in risk-shifting (top left panel, Fig. 8). Moreover, the optimal level of minimum bank capital requirement is now higher at 8.5%, attaining almost 1.5 percent

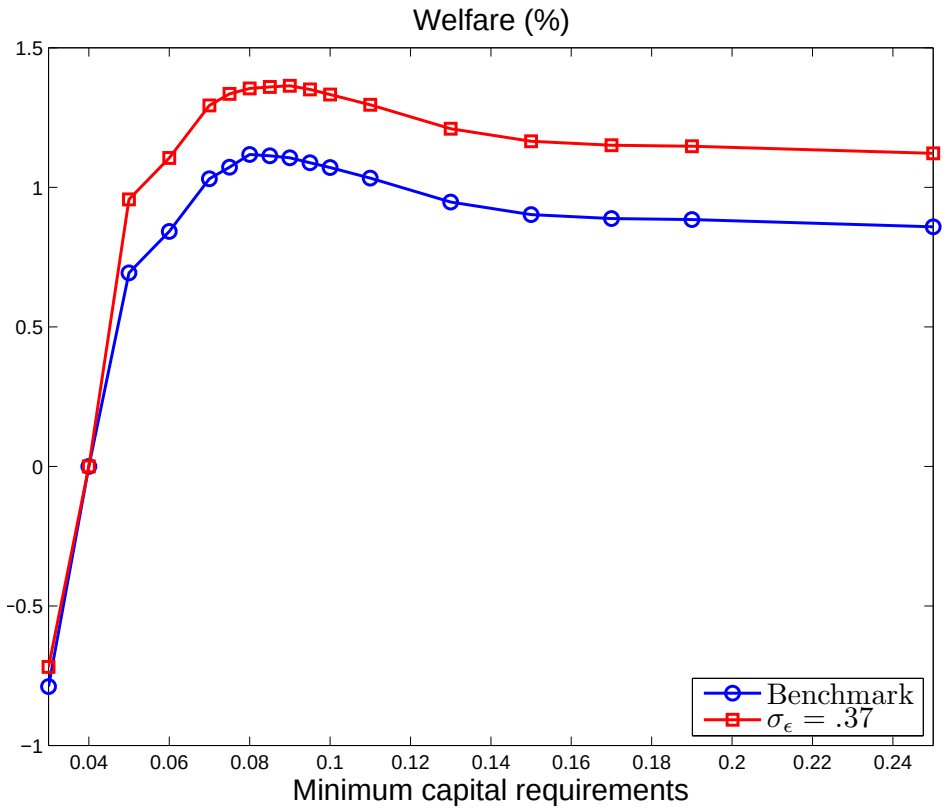


Fig. 9: Role of additional risk exposure due to risk-shifting σ_ϵ

Notes – This figure shows the welfare result as a function of the minimum capital requirement $\bar{e}$ relative to the benchmark calibration with $\bar{e} = .04$. Welfare is expressed in lifetime consumption units. The blue-circle line is welfare in the benchmark case ($\sigma_\epsilon = .363$), and the red-square line is for the case with $\sigma_\epsilon = .37$. All other parameters are as calibrated in Table 1. The x-axis indicates different levels of minimum capital requirement.

of lifetime consumption, while in the benchmark calibration the optimal level is 8%. This result is due to the fact that in spite of lower μ, the net negative effect of bank distortions is higher (lower average productivity, Fig. 8), and so the benefits of bank regulation is higher while the cost of regulation has not changed.

Role of additional risk exposure σ_ϵ. Fig. 9 compares welfare results in the benchmark case with the case where the additional risk exposure due to risk-shifting is higher. With higher risk exposure due to risk-shifting, the welfare gain is higher at the optimal level of capital requirement, 1.35% versus 1.1%. Moreover, the optimal capital ratio is also higher at 9% compared to 8% in the benchmark case. This is intuitive since the upside potential

of risk-shifting is higher, but the downside is unchanged, banks have more incentives to risk-shift when risk exposure is higher. This leads to more capital losses due to bank default and hence lowers investment productivity. Thus, from a social perspective, the cost of risk-shifting is higher, and so is the benefit of higher bank capital requirements. Since the cost of regulating banks is the same, this results in higher welfare gains and higher optimal level of minimum capital requirement.

5 Conclusion

This paper quantitatively studies the welfare implications of bank capital requirements in a dynamic general equilibrium banking model. In the proposed model, because of government bailouts, banks have incentives to risk-shift, leading to inefficient lending to risky-low-productivity firms. Bank capital requirements reduce risk-shifting incentives and improve welfare. The calibrated version of the model suggests that an 8% minimum Tier 1 capital requirement brings about a significant welfare improvement of 1.1% of lifetime consumption. This capital requirement is 2 percentage points *higher* than the level under Basel III and current U.S. regulation. Moreover, from a social perspective, the bank cost of equity in this model is not expensive. Welfare gains remain sizable even at a 25 percent minimum capital requirement. Overall, my results highlight the need to re-examine current bank capital regulations.

Further research should consider the impact of aggregate uncertainty on the optimal level of minimum capital requirement as well as welfare implications of countercyclical bank capital requirements policies. Moreover, the roles of other externalities such as contagious bank failures and asset fire sale, should be analyzed. Intuition suggests that these externalities would further strengthen the benefit of bank capital regulation now that the social cost of bank failure is higher. The optimal level of capital ratio would therefore be even higher than the 8% suggested by the proposed model.

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Appendices

A Data

Quarterly macro data comes from the BEA 1947-2010. Bank data comes from the Call Reports available at https://cdr.ffiec.gov/public/ and also available through the Wharton Research Data Services under the Bank Regulatory database. I screen and construct the time series used in this paper following Kashyap and Stein (2000); den Haan, Sumner, and Yamashiro (2007); Corbae and D'Erasmo (2012). In particular, I use U.S. commercial banks and define

- Return on loans = $\ln(1 + \text{Interest Income form C\&I loans/C\&I loans}) - \text{Inflation}$
- Net interest margin = Return on loans - Cost of deposits
- Cost of deposits = $\ln(1 + \text{Interest Expense from Deposits/Deposits}) - \text{Inflation}$
- Net charge-off rate = (C&I charge-offs - C&I recoveries)/C&I loans

Tier 1 capital is constructed as suggested by the Federal Reserve Bank of Chicago.[8] Tier 1 capital ratio is Tier 1 capital over risk weighted assets, and leverage ratio is Tier 1 capital over total assets. Failure and exit are weighted by assets and calculated from the FDIC fail bank list and the Federal Reserve Bank of Chicago Mergers and Acquisitions database.[9,10] Failure is when a bank failed and was not assisted by the FDIC. Exit includes failure and any bank that has its charter discontinued (merger code 1 and 50).

[8] See http://www.chicagofed.org/digital_assets/others/banking/financial_institution_reports/regulatory_capital.pdf

[9] Details at http://www2.fdic.gov/hsob/SelectRpt.asp?EntryTyp=30

[10] See http://www.chicagofed.org/webpages/publications/financial_institution_reports/merger_data.cfm

B Solution Method

The numerical solution for the model is similar to Gomes (2001) and proceeds in the following steps:

1. Guess a pricing kernel

2. From the guess in step 1, retrieve the growth rate of the economy and hence the total capital demanded by final good producers. This also gives the price of capital from equation (8).

3. Solve the bank's problem.

4. Check the free-entry condition (18), assuming positive entry. Update and repeat step 1 until convergence.

5. The mass of new banks, E_t are determined by the capital market clearing condition

$$I_t^d = I_t^s.$$

6. From the policy functions, one can derive the transition matrix defined in equation (20). For the net cash π_{t+1} that falls between grid points, I use linear interpolation to allocate the probability mass between the two adjacent points.

7. The stationary distribution of banks comes from inverting equation (19).

8. Once one has the stationary distribution, all variables are readily computed.