Markets, Banks and Shadow Banks

David Martinez-Miera
UC3M and CEPR

Rafael Repullo
CEMFI and CEPR

May 2018

Abstract

We analyze the effect of bank capital regulation on the structure and risk of the financial system. Banks intermediate between entrepreneurs and investors, and can screen entrepreneurs' projects, which reduces their default risk. Screening is costly but it is not observed by investors, so there is a moral hazard problem. Banks choose whether to be subject to the regulation, in which case a supervisor certifies their capital, or not be subject to it, in which case they have to resort to more expensive private certification. Market finance, regulated banks, and shadow banks can coexist in equilibrium. Under both flat and risk-based capital requirements, safer entrepreneurs borrow from the market and riskier entrepreneurs borrow from banks. The difference is that flat (risk-based) requirements are especially costly for relatively safe (risky) entrepreneurs which may be better off borrowing from shadow banks than from regulated banks, which results in higher default risk. We compare these regulations in terms of welfare, and characterize the optimal requirements taking into account the existence of both market and shadow bank finance.

JEL Classification: G21, G23, G28

Keywords: Bank capital requirements, bank supervision, credit screening, credit spreads, deposit insurance, financial structure, optimal risk-based regulation, shadow banks.

We thank Frederic Boissay (discussant), Philip Bond, Jean Edouard Colliard (discussant), Jose Fillat, Hans Degryse (discussant), Julian Kolm (discussant), David Miles (discussant), George Pennacchi (discussant), Jean-Charles Rochet, and Javier Suarez for useful comments. Financial support from the Spanish Ministry of Economy and Competitiveness, Grants No. ECO2014-59262-P (Repullo) and ECO2013-42849-P (Martinez-Miera), and from Banco de España (Martinez-Miera) is gratefully acknowledged. The work of Martinez-Miera has been prepared under the Lamfalussy Fellowship Program of the European Central Bank (ECB). The views expressed are those of its authors and do not represent those of the Banco de España, the ECB, or the Eurosystem. E-mail: david.martinez@uc3m.es, repullo@cemfi.es.

> "While higher capital and liquidity requirements on banks will no doubt help to insulate banks from the consequences of large shocks, the danger is that they will also drive a larger share of intermediation into the shadow banking realm."
>
> S. Hanson, A. Kashyap, and J. Stein (2011)

1 Introduction

The aftermath of the 2007-2009 financial crisis resulted in a widespread adoption of tougher banking regulation, exemplified by the 2010 agreement of the Basel Committee on Banking Supervision, known as Basel III. However, a concern has emerged about the possibility that the effectiveness of the new regulation may be hindered by a shift of intermediation away from the regulated banks and into the shadow banking system.

This paper proposes an analytical framework to understand the effects of different types of bank capital requirements on the structure and risk of the financial system. In particular, we address issues such as (i) what is the difference between regulated banks and shadow banks, and how do they differ from direct market finance, (ii) how does bank capital regulation affect funding through these channels, and (iii) how does the existence of shadow banks affect the effectiveness of capital regulation.

The framework builds on the model of Martinez-Miera and Repullo (2017), where a set of heterogeneous entrepreneurs borrow from competitive banks to fund their risky investment projects, and banks can reduce the probability of default by monitoring/screening these projects at a cost. Unlike in our previous setup, where banks only raised (uninsured) debt finance from a set of risk-neutral investors, here we introduce the possibility of banks raising costly equity finance and analyze the effect of different forms of capital requirements. We consider three possible modes of funding entrepreneurs' projects: they may be directly funded by the market, or through intermediaries that can be either regulated or shadow banks. Market finance differs from intermediated finance in that entrepreneurs are not monitored/screened. Both regulated and shadow banks monitor/screen their borrowers, but only the former comply with the regulation.

The shadow banking system has been described by the Financial Stability Board (FSB) as "credit intermediation involving entities and activities outside the regular banking system." Our activity-based notion of shadow banking is more closely related to the narrow measure put forward by the FSB, in which non-bank financial institutions (excluding insurance corporations and pension funds) are classified with reference to five economic functions, each of which involves non-bank credit intermediation.[1] The quantitatively most important of these functions, is defined as "the management of collective investment vehicles with features that make them susceptible to runs," which includes, in order of importance, fixed income funds, mixed (equity and credit) funds, money market mutual funds, and credit hedge funds.[2] One common feature of these institutions is that they actively select the assets in included their portfolios. For this reason, and in contrast with Martinez-Miera and Repullo (2017), this paper focuses on ex-ante screening (rather than ex-post monitoring) of borrowers by financial intermediaries.[3]

A key financial friction that is at the core of our approach is that screening is not observed by investors, so there is a moral hazard problem in intermediated finance. In this setup, (inside) equity capital provides "skin in the game" and hence serves as a commitment device for screening borrowers. For this reason, banks may be willing to use (more expensive) equity finance in order to ameliorate the moral hazard problem and reduce the cost of debt.[4]

However, for this channel to operate, the capital structure has to be observable to outside investors. Given the incentives of banks to save on costly equity, we assume that capital has to be certified by an external (private or public) agent. Public certification is done by

[1] This approach allows for "...the exclusion of entities that are not typically part of a credit intermediation chain or, if they are, they are not involved in significant maturity/liquidity transformation and/or leverage." See Financial Stability Board (2018, p. 45).

[2] At end-2016, this function amounted to 71.6% of the total narrow measure of $45.2 trillion in the 29 jurisdictions covered in the report; see Financial Stability Board (2018). The other functions are securitization-based credit intermediation and funding of financial entities (9.6%), intermediation of market activities that is dependent on short-term funding or on secured funding of client assets (8.4%), loan provision that is dependent on short-term funding (6.4%), and facilitation of credit creation (0.4%).

[3] The screening setup is essentially identical to the one in Helpman, Itskhoki and Redding (2010), where firms can increase the average ability of the workers they hire by incurring a screening cost.

[4] In this setup if capital were not more expensive than debt, banks would be 100% equity financed. In such case there would be no financial friction and no need of regulation.

a bank supervisor that verifies whether banks that choose to be regulated comply with the regulation. The capital of banks that choose not to be regulated is not certified by the supervisor, so they have to resort to private certification, which we assume to be more expensive. Thus, (cheaper) public certification is tied to complying with a regulation that might be very tough, at least for banks financing certain types of projects. For this reason, (shadow) banks might prefer not to comply with the regulation and resort to private certification. Thus, in this setup the emergence of shadow banks is linked to a trade-off between the costs and benefits of public certification. An alternative setup, examined in Appendix A with essentially the same results on the equilibrium structure of the financial system, assumes that the advantage of regulated banks relative to shadow banks comes from the existence of underpriced deposit insurance instead of lower certification costs.

We consider two different types of regulation, namely risk-insensitive (or flat) and risk-sensitive capital requirements. The former broadly correspond to the 1988 Accord of the Basel Committee (Basel I),[5] while the latter correspond to the 2004 (Basel II) and 2010 (Basel III) Accords. We follow the Basel II and III approach of using a Value-at-Risk (VaR) criterion to determine the risk-sensitive requirements.[6] We highlight the different effects that these regulations have on the equilibrium market structure, with especial emphasis on whether they will shift some types of lending from regulated banks into shadow banks or direct market finance, and their impact on the overall risk of the financial system.

Specifically, under both regulations, and due to the benefit of screening, safer entrepreneurs will borrow from the market and riskier entrepreneurs will borrow from intermediaries. The difference between them is that flat requirements are especially costly for relatively safe entrepreneurs, that may be better off borrowing from shadow banks, while VaR based requirements are especially costly for risky entrepreneurs, that may be better off borrowing from shadow banks. With flat requirements the equilibrium market structure is such that regulated banks always fund the riskiest projects, while if shadow banks operate they fund

[5] This also corresponds to the leverage ratio proposed by Admati and Hellwig (2013).

[6] See, for example, Gordy, Heitfield and Wu (2015). Basel III combines risk-sensitive VaR based capital requirements with a risk-insensitive leverage ratio.

projects that are safer than those of the regulated banks. With VaR based capital requirements the equilibrium market structure is such that regulated banks always fund the intermediate risk projects, while if shadow banks operate they fund the riskiest projects.

The results illustrate how the existence of shadow banks affect the effectiveness of the different types of regulation. Tightening flat (VaR based) capital requirements increases the screening incentives of banks for which the regulation is binding at the cost of driving some safer (riskier) entrepreneurs to the shadow banking system, where they will have lower screening and higher default risk.

After analyzing the effect of these regulations on the structure and risk of the financial system, we compare them in terms of welfare for a specific parameterization of the model. We compute the optimal flat and VaR based requirements, as well as the optimal capital requirements, showing that these requirements are risk-sensitive but they differ significantly from those derived from a VaR criterion. In particular, the corresponding confidence level is lower for riskier loans.[7]

We then analyze how the equilibrium structure and risk of the financial system change with two key parameters of the model, namely the expected return required by investors (the safe rate) and the excess cost of bank capital. We find that for both types of capital requirements a higher safe rate and/or a lower cost of capital expand the range of entrepreneurs financed by regulated banks. According to these results, the shadow banking system will thrive when the safe rate is low (due, for example, to a savings glut) and the cost of bank capital is high (due, for example, to the relative scarcity of bank capital following a bubble-driven expansion of banks' balance sheets). In a second extension we analyze a variation of the model in which the cost of capital is endogenously derived from a fixed supply of bank capital. In this case, tightening capital requirements affects all banks in the economy through the increase in the equilibrium cost of capital, which leads to lower capital and higher risk of those (regulated and shadow) banks not constrained by the regulation.

[7] This effect goes in the same direction as the reduction in the correlation parameter for riskier loans in Basel II and Basel III.

Finally, we show in an Appendix that the qualitative results on the equilibrium structure of the financial system remain unchanged when the advantage of regulated banks relative to shadow banks comes from the existence of underpriced deposit insurance instead of a lower cost of capital certification.

Literature review This paper is related to a long standing strand of research analyzing the role of capital requirements on banks' risk-taking decisions; see Koehn and Santomero (1980), Rochet (1992), Hellmann et al. (2000), and Repullo (2004), among many others. We depart from this strand of research as we endogeneize the return structure faced by financial intermediaries in a perfectly competitive environment.[8] Our second departure is related to the fact that, as Hanson et al. (2011) highlight, we analyze relevant trade-offs that appear when the existence of unregulated financial intermediaries (shadow banks) is taken into account. Recent empirical studies such as Buchak et al. (2017), analyzing the mortgage market, and Irani et al. (2018), analyzing the (syndicated) corporate loan market, show how, as predicted by our model, stricter capital requirements are linked to an expansion of the shadow banking system.

Our focus in understanding the emergence of shadow banks relates our research to a recent strand of theoretical banking literature. In contrast to Plantin (2015) that focuses on the different ability of shadow banks to issue money-like liabilities, or Bengenau and Landvoigt (2017) that focus on the impact of bailouts as a key difference between regulated and shadow banks, we consider a novel trade-off between the costs and benefits of regulation, where the latter are linked to the savings on certification costs by bank supervision. It is important to highligh that in constrast to the arguments in Acharya et al. (2013), our paper does not build on regulatory arbitrage and implicit subsdies received by shadow banks through their linkages to regulated banks, as in our setup regulated and shadow banks are separate entities without any direct linkages.[9]

[8] See for example Harris et al. (2017) or Martinez-Miera (2009) for other papers analyzing how capital regulation can shape the endogenous return of financial assets and by doing so impact the banks' risk-taking decisions.

[9] See Fahri and Tirole (2017) for a more extensive review on different elements that can explain the nature of the shadow banking sector. These elements include, but are not limited to, the role of financial

Our main emphasis on banks' incentive compatibility and participation constraints links our results to those of Fahri and Tirole (2017) who highlight the relevance of banks' decisions to become shadow banks in the presence of deposit insurance and a lender of last resort. In contrast to their work, our model focuses on the impact of banks' moral hazard in the absence of any explicit or implicit deposit insurance. However, we also acknowledge (and analyze in an Appendix) the relevance of underpriced deposit insurance for the regulated banks as a possible factor explaining the emergence of shadow banks.

Finally, our focus on understanding how moral hazard shapes the financial landscape relates our model to the seminal paper of Hölmstrom and Tirole (1997). They show how in a laissez-faire economy financial intermediaries can use capital to ameliorate moral hazard problems and how (when capital is costly) this gives rise to intermediated and market finance. In contrast to having entrepreneurial wealth as key determinant of the financing mode, following Martinez-Miera and Repullo (2017) we focus on ex-ante differences in the risk of entrepreneurial projects. We also analyze how the structure of the financial sector is affected by capital regulation, which is absent in either of these two papers.

Structure of the paper Section 2 presents the model of bank lending under moral hazard in which banks are not regulated and have to pay a cost to certify their capital. Section 3 introduces bank capital regulation and supervision, analyzes the effects of flat and Value-at-Risk based minimum capital requirements on the structure and risk of the financial system. Section 4 compares these regulations in terms of welfare, and characterizes the optimal capital requirements. Section 5 considers the effect of changes in funding costs and of endogenizing the cost of capital. Appendix A examines an alternative setup in which the advantage of regulated banks relative to shadow banks comes from the existence of underpriced deposit insurance, and Appendix B contains the proofs of the analytical results.

intermediaries as producers of safe assets (Hanson et al., 2015) and of liquidity services (Moreira and Savov, 2017).

2 The Model

Consider an economy with two dates ($t = 0, 1$), a large set of penniless entrepreneurs with observable types $p \in [0, \overline{p}] \subseteq [0, 1]$, and a large set of investors characterized by an infinitely elastic supply of funds at an expected return equal to R_0 (the safe rate). Entrepreneurs have investment projects that require external finance. Such finance may come directly from investors (market finance) or may be intermediated by banks (bank finance).

Intermediated finance differs from direct market finance in two respects. First, banks screen their borrowers, which reduces their default risk, whereas markets do not. Second, banks raise funds from investors, in the form of uninsured deposits, and also from (inside) shareholders. We assume that bank capital is costly. Specifically, there is an infinitely elastic supply of bank capital at an expected return equal to $R_0 + \delta$, where the excess cost of bank capital δ is positive.

Each entrepreneur of type p has a project that requires a unit investment at $t = 0$ and yields a stochastic return $\widetilde{A}_p$ at $t = 1$ given by

$$\widetilde{A}_p = \begin{cases} A(x_p), & \text{with probability } 1 - p + s_p, \\ 0, & \text{with probability } p - s_p, \end{cases} \tag{1}$$

where the success return $A(x_p)$ is a decreasing function of the aggregate investment x_p of entrepreneurs of type p, and $s_p \in [0, p]$ is the screening intensity of the entrepreneur's lender.[10] When $s_p = 0$ we have direct market finance, and when $s_p > 0$ we have bank finance. Thus, the safest type $p = 0$ will always be funded by the market. Screening is not observed by the investors, so there is a moral hazard problem.

Screening increases the probability of success of entrepreneurs' projects but entails a cost $c(s_p)$. The screening cost function $c(s_p)$ satisfies $c(0) = c'(0) = 0$, and $c'(s_p) > 0$, $c''(s_p) > 0$, and $c'''(s_p) \geq 0$, for $s_p > 0$. A special case that satisfies these assumptions and will be used

[10] The important function that financial intermediaries perform is to reduce the informational asymmetries between entrepreneurs and investors. This can be done by screening the quality of entrepreneurs' projects ex-ante or by monitoring them ex-post. In the latter case, the screening intensity s_p would be replaced by the monitoring intensity m_p. Although the interpretation of what intermediaries do is different, both models yield the same results.

for our numerical results is the quadratic function

$$c(s_p) = \frac{\gamma}{2}(s_p)^2, \tag{2}$$

where $\gamma > 0$.

To simplify the presentation we assume that (i) the returns of the projects of entrepreneurs of each type p are perfectly correlated, and (ii) for each type p there is a single bank that specializes in funding entrepreneurs of this type. The perfect correlation assumption is made for convenience, and could be easily relaxed. The assumption that a single bank lends to each type of entrepreneurs not restrictive, since we will assume that the loan market is contestable. The key simplifying assumption is that no bank lends to more than one type, since otherwise we would have to model bank competition across types.[11]

Under these conditions, the assumption $A'(x_p) < 0$ may be rationalized by introducing a representative consumer with a utility function over the continuum of goods produced by entrepreneurs of types $p \in [0, \overline{p}]$. Specifically, suppose that one unit of investment produces (if successful) one unit of output, and consider the utility function

$$U(q, x) = q + \frac{\sigma}{\sigma - 1}\int_0^{\overline{p}} (x_p)^{\frac{\sigma-1}{\sigma}}\, dp, \tag{3}$$

where q is the consumption of a composite good, $x = \{x_p\}_{p\in[0,\overline{p}]}$, and $\sigma > 1$. The budget constraint of the representative consumer is

$$q + \int_0^{\overline{p}} A_p x_p\, dp = I, \tag{4}$$

where A_p is the unit price of the good produced by entrepreneurs of type p, and I is her (exogenous) income. Maximizing (3) subject to (4) gives a first-order condition that implies

$$A_p = A(x_p) = (x_p)^{-1/\sigma}. \tag{5}$$

Thus, the higher the investment x_p of entrepreneurs of type p the lower the equilibrium price A_p, if the investment is successful. If it is not, output will be zero and the representative

[11]It should be noted that this assumption is not restrictive in the model with deposit insurance, since in this case competitive banks would want to specialize in a single type of loans; see Lemma 1 in Repullo and Suarez (2004).

consumer will not consume this good.[12]

We assume free entry of entrepreneurs in the loan market. Hence, if the lowest loan rate for entrepreneurs of type p offered by either markets or banks is R_p, then a measure x_p of these entrepreneurs will enter until $A(x_p) = R_p$. Thus, entrepreneurs will only be able to borrow at a rate that leaves them no surplus.

Since investors are characterized by an infinitely elastic supply of funds at an expected return equal to R_0, the equilibrium loan rate R_p^* for entrepreneurs of type p under direct market finance will be the rate that satisfies the participation constraint

$$(1-p)R_p^* = R_0. \tag{6}$$

Computing the equilibrium loan rate under bank finance is more complicated because one has to derive banks' decision on capital and screening. To do this, we assume that the loan market is contestable. Thus, although there is a single bank that lends to each type, the incumbent would be undercut by another bank (or by the market) if it were profitable to do so.

Despite the assumption that bank capital is more expensive than debt, banks may be willing to use equity finance in order to ameliorate the moral hazard problem and reduce the cost of debt. But this requires that banks' capital structure be observable to outside investors. Given the incentives of banks to save on costly equity, we assume that capital has to be certified by an external agent at a cost η per unit of capital.[13]

The bank lending to entrepreneurs of type p will raise $1-k_p$ funds per unit of loans from investors at a rate B_p (the rest will be funded with capital), set a loan rate R_p, and choose a screening intensity $s_p \in [0, p]$. By contestability, the equilibrium loan rate R_p^* for entrepreneurs of type p will be the lowest feasible rate.

Formally, an *equilibrium* for entrepreneurs of type p under bank finance is an array $(k_p^*, B_p^*, R_p^*, s_p^*)$ that minimizes the loan rate R_p subject to the bank's incentive compatibility

[12] An alternative rationalization may be derived from the demand of a set of final good producers that use entrepreneurs' output as an intermediate input; see Martinez-Miera and Repullo (2017).

[13] Alternatively, we could assume a certification cost per unit of loans, that is proportional to the banks' balance sheet. This setup is analytically less tractable than simply adding η to the cost of capital δ, but the main qualitative results would remain unchanged.

constraint

$$s_p^* = \arg\max_{s_p} \left[(1-p+s_p)[R_p^* - (1-k_p^*)B_p^*] - c(s_p)\right], \tag{7}$$

the shareholders' participation constraint

$$(1-p+s_p^*)[R_p^* - (1-k_p^*)B_p^*] - c(s_p^*) - \eta k_p^* \geq (R_0+\delta)k_p^*, \tag{8}$$

and the investors' participation constraint

$$(1-p+s_p^*)B_p^* \geq R_0. \tag{9}$$

The incentive compatibility constraint (7) characterizes the bank's choice of screening s_p^* given that the bank gets R_p^* and pays $(1-k_p^*)B_p^*$ with probability $1-p+s_p$ (and with probability $p-s_p$ gets zero, by limited liability). The participation constraints (8) and (9) ensure that the shareholders and the investors get the required expected return on their investments.

Note that the assumption that project returns are perfectly correlated implies that the bank's return per unit of loans is identical to the individual project return, which is given by (1). It also implies that the loans' probability of default equals the bank's probability of failure.

To ensure that market and bank finance coexist in equilibrium, we assume that the screening cost function is sufficiently convex. In particular,

$$c''(0) > \frac{R_0(R_0+\delta)}{\delta}. \tag{10}$$

The following result characterizes the range of entrepreneurs' types that borrow from the market and from banks.

Proposition 1 *There exists a marginal type*

$$\widehat{p} = 1 - \sqrt{\frac{R_0(R_0+\delta+\eta)}{(\delta+\eta)\,c''(0)}} \tag{11}$$

such that entrepreneurs of types $p \leq \widehat{p}$ will borrow from the market and entrepreneurs of types $p > \widehat{p}$ will borrow from banks.

The sketch of the proof is as follows. Consider a type p for which the equilibrium screening intensity s_p^* satisfies $0 < s_p^* < p$. Then the bank's incentive compatibility constraint (7) reduces to the first-order condition

$$R_p^* - (1 - k_p^*)B_p^* = c'(s_p^*). \tag{12}$$

From here it can be shown (see the formal proof in the Appendix) that both the shareholders' participation constraint (8) and the investors' participation constraint (9) will be binding. Solving for $R_p^* - (1 - k_p^*)B_p^*$ in the shareholders' participation constraint (8), substituting it into the first-order condition (12), and solving for k_p^* gives

$$k_p^* = \frac{(1 - p + s_p^*)c'(s_p^*) - c(s_p^*)}{R_0 + \delta + \eta}. \tag{13}$$

By the properties of the screening cost function $c(s_p)$ this equation implies that $k_p^* > 0$ if and only if $s_p^* > 0$.[14] In other words, *banks will always want to have a positive amount of capital.*

Next, solving for B_p^* in the investors' participation constraint (9), substituting it into the first-order condition (12), and rearranging gives

$$R_p^* = \frac{(1 - k_p^*)R_0}{1 - p + s_p^*} + c'(s_p^*). \tag{14}$$

The equilibrium loan rate R_p^* is found by minimizing (14) with respect to s_p and k_p subject to (13). Finally, we show that for entrepreneurs of types $p \leq \widehat{p}$, the loan rate (14) is minimized by setting $s_p^* = k_p^* = 0$, so they will borrow from the market, and for entrepreneurs of types $p > \widehat{p}$, the loan rate (14) is minimized by setting $s_p^* > 0$ and $k_p^* > 0$, so they will borrow from banks.

In what follows we introduce two possible institutions that may certify banks' capital. One is a *private auditor* that charges a rate η_1 per unit of capital. The other is a *public auditor* that charges a rate η_0 per unit of capital. The presence of a public auditor may be justified by introducing bank capital requirements and associating the public auditor to a bank supervisor that verifies whether the bank complies with the regulation. We assume that

[14] Note that by the convexity of the screening cost function $s_p^* c'(s_p^*) > c(s_p^*)$, for $s_p^* > 0$.

private certification is costlier than public certification, so $\eta_1 > \eta_0$. This may be rationalized by assuming that supervisors have lower agency problems than private auditors or have better access to relevant bank information.

But if private auditors are more expensive than the public auditor, why would banks want to resort to them? The answer is that using the public auditor is tied to complying with a regulation that might be very tough, at least for banks financing certain types of entrepreneurs. These (shadow) banks might then prefer not to comply with the regulation and resort to private auditors. In this manner, the possible emergence of a shadow banking system is linked to a trade-off between the costs and benefits of public certification.

Bank capital requirements will be introduced in the next section. Here we present, for future reference, the comparative static properties of the model with respect to the cost of certification.

Proposition 2 *An increase in the certification cost η expands the range $[0, \widehat{p}]$ of market finance, and for types $p > \widehat{p}$ reduces banks' equilibrium capital and screening and increases their probability of failure.*

Figure 1 illustrates this result for the quadratic screening cost function (2) and two values of the certification cost, η_0 and η_1, corresponding respectively to a public and a private auditor. To simplify the presentation, in what follows we will normalize to zero the cost of the public auditor ($\eta_0 = 0$), and drop the subindex for the cost of the private auditor ($\eta_1 = \eta$). Panel A shows that an increase in the certification cost shifts to the right from $\widehat{p}_0$ to $\widehat{p}_1$ the marginal type that is indifferent between market and bank finance. As capital becomes more expensive, due to the higher certification costs, banks reduce their capital per unit of loans. Panel B shows the effect on the probability of failure $p - s_p$. Under market finance $s_p = 0$, so the probability of failure coincides with the 45^o line. The reduction in the level of capital under high certification costs worsens the banks' moral hazard problem and leads to an increase in their probability of failure.

[FIGURE 1]

Summing up, we have presented a model in which a heterogeneous set of entrepreneurs seek funding from either banks or the market. The difference between bank and market finance is that banks screen their borrowers, which leads to a reduction in their probability of failure. Bank screening is subject to a moral hazard problem that can be ameliorated by equity capital. However, capital is costlier than deposits, and also requires paying a certification cost. We have shown that safer entrepreneurs borrow from the market while riskier entrepreneurs borrow from banks, and that banks will always want to fund part of their lending with capital. Higher certification costs shift some entrepreneurs from bank to market finance, and increase the banks' probability of failure.

3 Bank Capital Regulation

This section introduces a *bank regulator* that sets minimum capital requirements and a *bank supervisor* that verifies whether banks that choose to be regulated comply with the regulation, in which case their capital is certified at a cost that is normalized to zero. Banks that choose not to be subject to the regulation will be called *shadow banks*. Since their capital is not certified by the supervisor, they will have to resort to more expensive private certification.

Two types of minimum capital requirements, flat and risk-based, will be analyzed. A flat requirement does not vary with the bank's risk, whereas a risk-based requirement is increasing in the bank's risk. The risk-insensitive regulation broadly corresponds to the 1988 Basel Capital Accord (Basel I), while the risk-sensitive regulation corresponds to the 2004 Revised International Capital Framework (Basel II) and the 2010 Global Regulatory Framework (Basel III).[15] In particular, we follow the Basel II and Basel III approach of using a value-at-risk criterion to determine the requirements for the different types of risks. We highlight the different impact that these regulations have on the equilibrium market structure of our model, with especial reference to the extent to which they will shift some types of lending into the shadow banking system.

[15] See Basel Committee on Banking Supervision (2015).

3.1 Flat capital requirements

Suppose that regulated banks are required to fund at least a proportion $\overline{k}$ of their lending with capital, independently of their type p. In this case, we show that when the requirement $\overline{k}$ is low, safer entrepreneurs borrow from the market while riskier entrepreneurs borrow from regulated banks. However, when the requirement $\overline{k}$ raises above a threshold the equilibrium of the model changes, with safer entrepreneurs borrowing from the market, medium risk entrepreneurs borrowing from shadow banks, and higher risk entrepreneurs borrowing from regulated banks.

To characterize the equilibrium under flat capital requirements, consider a bank lending to entrepreneurs of type $p \geq \widehat{p}_0$, where $\widehat{p}_0$ denotes the marginal type that is indifferent between market and bank finance under zero capital requirements and zero certification costs.[16] Clearly, if the bank would like to have more capital than the minimum required by regulation, that is if $k_p \geq \overline{k}$, the capital requirement would not have any effect. However, if the bank would like to have less capital than $\overline{k}$, one can show that if k_p is very close to zero, then complying with the regulation has high costs so these entrepreneurs shift to market finance. On the other hand, if k_p is very close to $\overline{k}$, then complying with the regulation has low costs so these entrepreneurs are funded by regulated banks.

What happens when k_p is between zero and $\overline{k}$ depends on the level of the capital requirement. When $\overline{k}$ is low there is a marginal type p_m that switches from market to regulated bank finance. When $\overline{k}$ is high shadow banks can profitably enter the market, and there is a marginal type p_m that switches from market to shadow bank finance and a marginal type $p_s > p_m$ that switches from shadow to regulated bank finance. Thus, we can state the following result.

Proposition 3 *If the minimum capital requirement $\overline{k}$ is below a threshold $\widehat{k}$, there is a marginal type $p_m > \widehat{p}_0$ such that entrepreneurs of types $p \leq p_m$ will borrow from the market and entrepreneurs of types $p > p_m$ will borrow from regulated banks. If the minimum requirement $\overline{k}$ is above the threshold $\widehat{k}$, there are two marginal types, $p_m < p_s$, such that entrepreneurs of*

[16] By Proposition 1, $\widehat{p}_0$ is given by (11) for $\eta = \eta_0 = 0$.

types $p \leq p_m$ will borrow from the market, entrepreneurs of types $p_m < p \leq p_s$ will borrow from shadow banks, and entrepreneurs of types $p > p_s$ will borrow from regulated banks.

Figure 2 illustrates the result for the case of a low minimum capital requirement ($\overline{k} \leq \widehat{k}$). Panel A shows equilibrium bank capital. Two regions may be distinguished. To the left of the marginal type p_m entrepreneurs borrow from the market. To the right of the marginal type p_m entrepreneurs borrow from regulated banks, with the safer ones borrowing from banks with binding capital $\overline{k}$ and the riskier ones borrowing from banks with nonbinding capital $k_p > \overline{k}$. Panel B shows the corresponding probabilities of failure $p - s_p$, which jump down at p_m because of the effect of the binding capital requirements.

[FIGURE 2]

Figure 3 illustrates the result for the case of a high minimum capital requirement ($\overline{k} > \widehat{k}$). Panel A shows equilibrium bank capital. Three regions may be distinguished. To the left of the marginal type p_m entrepreneurs borrow from the market, between p_m and p_s entrepreneurs borrow from shadow banks, and to the right of the marginal type p_s entrepreneurs borrow from regulated banks.[17] Panel B shows the corresponding equilibrium probabilities of failure $p - s_p$, which bend down at p_m where shadow banks start to operate, and jump down at p_s because of the effect of the binding capital requirements.

[FIGURE 3]

Thus, although tightening flat capital requirements reduces the probability of failure of relatively safe banks in the regulated banking system, this comes at the cost of pushing some entrepreneurs toward alternative sources of funding (market finance or shadow banks), which reduces screening and increases the probability of default.

It should be noted that with flat capital requirements the equilibrium market structure of the financial sector is such that regulated banks always fund the riskiest projects, while if

[17] Notice that p_m coincides with the marginal type $\widehat{p}_1$ that is indifferent between market and bank finance under zero capital requirements and positive certification costs. By Proposition 1, $\widehat{p}_1$ is given by (11) for $\eta = \eta_1 > 0$.

shadow banks operate they fund projects that are ex-ante safer than those of the regulated banks (although not necessarily ex-post, given their different screening incentives).

3.2 Value-at-Risk based capital requirements

The risk-sensitive minimum capital requirements for credit risk of Basel II and Basel III are based on the criterion that capital should cover the losses of a sufficiently diversified loan portfolio with a confidence level $1-\alpha = 0.999$ (99.9%). To translate this Value-at-Risk (VaR) criterion to our model setup, in which loan defaults are perfectly correlated, we will define a capital requirement $\bar{k}_p$ such that the probability of default $p - s_p^*$ of the loans to entrepreneurs of type p is equal to α.

By Proposition 1, there is an equilibrium relationship between capital and screening given by (13). Solving for s_p^* in the condition $p - s_p^* = \alpha$, and substituting it into (13), and setting the certification cost $\eta = 0$ then gives the model equivalent of the Basel formula

$$\bar{k}_p = \begin{cases} 0, & \text{if } p \leq \alpha, \\ \dfrac{(1-\alpha)\, c'\,(p-\alpha) - c(p-\alpha)}{R_0 + \delta}, & \text{otherwise.} \end{cases} \tag{15}$$

Notice that for $p > \alpha$ we have

$$\frac{d\bar{k}_p}{dp} = \frac{(1-\alpha)\, c''\,(p-\alpha) - c'(p-\alpha)}{R_0 + \delta}.$$

Thus, riskier banks will be required to have more capital if $(1-\alpha)\, c''\,(p-\alpha) - c'(p-\alpha) > 0$, which holds by the properties of the screening cost function.[18]

We next show that when the confidence level $1-\alpha$ is low, safer entrepreneurs borrow from the market while riskier entrepreneurs borrow from regulated banks. However, when the confidence level $1-\alpha$ raises above a threshold the equilibrium of the model changes, with safer entrepreneurs borrowing from the market, medium risk entrepreneurs borrowing from regulated banks, and higher risk entrepreneurs borrowing from shadow banks. Thus, in contrast with the equilibrium under flat capital requirements, here if shadow banks operate they fund projects that are ex-ante riskier than those of the regulated banks.

[18] To see this notice that $(1-\alpha)\, c''\,(p-\alpha) - c'(p-\alpha) > (p-\alpha)\, c''\,(p-\alpha) - c'(p-\alpha) \geq 0$. For the quadratic monitoring cost function (2) the condition simplifies to $\gamma(1-p) > 0$.

Proposition 4 *If the confidence level* $1-\alpha$ *is below a threshold* $1-\widehat{\alpha}$*, there is a marginal type* p_s *such that entrepreneurs of types* $p \leq p_m$ *will borrow from the market and entrepreneurs of types* $p > p_m$ *will borrow from regulated banks. If the confidence level* $1-\alpha$ *is above the threshold* $1-\widehat{\alpha}$*, there are two marginal types,* $p_m < p_s$*, such that entrepreneurs of types* $p \leq p_s$ *will borrow from the market, entrepreneurs of types* $p_m < p \leq p_s$ *will borrow from regulated banks, and entrepreneurs of types* $p > p_s$ *will borrow from shadow banks.*

Figure 4 illustrates the result for the case of a low confidence level ($\alpha > \widehat{\alpha}$). Panel A shows equilibrium bank capital. Two regions may be distinguished. To the left of the marginal type p_m entrepreneurs borrow from the market.[19] To the right of the marginal type p_m entrepreneurs borrow from regulated banks, with the safer ones borrowing from banks with nonbinding capital $k_p > \overline{k}_p$ and the riskier ones borrowing from banks with binding capital $\overline{k}_p$. Panel B shows the corresponding probabilities of failure $p - s_p$, which become equal to α for high-risk banks.

[FIGURE 4]

Figure 5 illustrates the result for the case of a high confidence level ($\alpha < \widehat{\alpha}$). Panel A shows equilibrium bank capital. Three regions may be distinguished. To the left of the marginal type p_m entrepreneurs borrow from the market, between p_m and p_s entrepreneurs borrow from regulated banks, and to the right of the marginal type p_s entrepreneurs borrow from shadow banks. Panel B shows the corresponding probabilities of failure $p - s_p$, which jump up at p_s when lending switches to shadow banks.

[FIGURE 5]

Thus, although tightening VaR based capital requirements reduces the probability of failure of relatively risky banks in the regulated banking system, this comes at the cost of

[19] Notice that p_m coincides with the marginal type $\widehat{p}_0$ that is indifferent between market and bank finance under zero capital requirements and zero certification costs.

pushing the riskiest entrepreneurs to the shadow banking system, which reduces screening and increases the probability of default.[20]

It should be noted that with VaR based capital requirements the equilibrium market structure of the financial sector is such that regulated banks always fund the medium risk projects, while if shadow banks operate they always fund the riskiest (ex-ante and ex-post) projects.

4 Optimal Capital Requirements

This section characterizes optimal capital requirements. We start by determining the optimal flat and VaR based requirements, taking into account that the funding of some entrepreneurs will endogenously take place through markets and/or shadow banks. Then, we characterize the optimal unconstrained capital requirements, showing that they are risk-sensitive, but with a slope smaller than that of the VaR based requirements (except for safer types for which the optimal VaR based capital requirement is zero).

To derive the social welfare function, we first note that by the proof of Proposition 1 the shareholders' participation constraint (8) and the investors' participation constraint (9) are satisfied with equality, which means that they exactly receive the opportunity cost of their funds. Moreover, by the assumption of free entry of entrepreneurs, they will only be able to borrow at a rate that leaves them no surplus.

Hence, social welfare reduces to the utility of the representative consumer. Substituting the budget constraint (4) into the utility function (3), and taking into account the fact that the goods of entrepreneurs of type p are produced with probability $1-p+s_p$, yields

$$W(x) = I + \frac{\sigma}{\sigma-1}\int_0^{\overline{p}} (1-p+s_p)\,(x_p)^{\frac{\sigma-1}{\sigma}}\,dp - \int_0^{\overline{p}} (1-p+s_p)A_p x_p\,dp,$$

where $x = \{x_p\}_{p\in[0,\overline{p}]}$ denotes an investment allocation. Substituting the first-order condition

[20] The empirical results of Grill, Kalyaeva, and Lambert (2018) show that higher capital requirements make the banking sector as a whole more reluctant to hold risky assets. Thus, they are in line with this prediction.

(5) into this expression then gives the social welfare function

$$W(x) = I + \frac{1}{\sigma - 1} \int_0^{\overline{p}} (1 - p + s_p)\,(x_p)^{\frac{\sigma-1}{\sigma}}\, dp. \tag{16}$$

Any bank capital regulation is described by a function $\overline{k}_p$ that gives the minimum capital requirement for loans to entrepreneurs of type $p \in [0, \overline{p}]$. If $\overline{k}_p = \overline{k}$ we have flat capital requirements, whereas if $\overline{k}_p$ is given by (15) we have VaR based capital requirements for a confidence level $1 - \alpha$.

By our previous results, a bank capital regulation $\overline{k}_p$ implies an equilibrium market structure and a corresponding equilibrium loan rate R_p for each type p of entrepreneur. Since entrepreneurs of type p will enter the market until $R_p = A(x_p) = (x_p)^{-1/\sigma}$, the equilibrium aggregate investment x_p of entrepreneurs of type p will be

$$x_p = (R_p)^{-\sigma}. \tag{17}$$

Hence, we can compute the social welfare $W(x)$ associated with any bank capital regulation.

4.1 Optimal flat and VaR based capital requirements

Optimal flat capital requirements are given by

$$\bar{k}^* = \arg\max_{\bar{k}} W(\overline{x}),$$

where $\overline{x}$ denotes the equilibrium investment allocation corresponding to the flat capital requirement $\bar{k}$.

The confidence level of the optimal VaR based capital requirements is given by

$$\alpha^* = \arg\max_{\alpha} W(x_\alpha),$$

where x_α denotes the equilibrium investment allocation corresponding to a VaR based capital requirement with confidence level $1 - \alpha$.

Figure 6 shows the optimal flat and VaR based capital requirements, together with the corresponding probabilities of failure $p - s_p$, for the parameterization used in Section 3. As previously argued, flat capital requirements are such that relatively safe entrepreneurs may borrow from shadow banks, while VaR requirements are such that high risk entrepreneurs may borrow from shadow banks. In our parametrization, while the optimal flat capital requirements result in shadow banks funding entrepreneurs with $p_m^f < p < p_s^f$, the optimal confidence level $1 - \alpha^*$ is sufficiently low so that no shadow banks operate in equilibrium.

[FIGURE 6]

To compare these two regulations we can compute the social welfare W_p associated with the equilibrium investment x_p of entrepreneurs of type p, which is given by

$$W_p = \frac{1}{\sigma - 1}(1 - p + s_p)\,(x_p)^{\frac{\sigma-1}{\sigma}}$$

Let W_p^f and W_p^v denote the value of W_p for the optimal flat and VaR based requirements. Figure 7 shows that the difference $W_p^v - W_p^f$ is positive for relatively low and high risk entrepreneurs, and it is negative for intermediate risk entrepreneurs. Hence, changing from the optimal flat to the optimal VaR based capital requirements generates heterogenous effects on the contribution to overall welfare of the different types of entrepreneurs. However, for our parameterization, the optimal VaR based requirement entails higher overall welfare than the optimal flat requirement.

[FIGURE 7]

4.2 Optimal capital requirements

Optimal unconstrained capital requirements are defined by

$$k_p^* = \arg\max_{k_p} W(x^*),$$

where x^* denotes the equilibrium investment allocation corresponding to the capital requirement k_p.

Figure 8 shows the optimal unconstrained capital requirements, together with the corresponding probabilities of failure $p - s_p$, for the parameterization used in Section 3. Such requirements are risk-sensitive, but they are different from the ones that come out from a VaR based regulation. In particular, they leave no room for shadow banks in order to save on certification costs. To achieve this, the optimal capital requirements are such that banks' probabilities of failure are increasing in the type p. This should be contrasted with VaR based requirements where the probability of failure of the regulated banks is equal (when the requirements are binding) to the given confidence level $1-\alpha$.

[FIGURE 8]

5 Extensions

This section discusses how the equilibrium structure and risk of the financial system evolves when (i) there are exogenous changes in the safe rate or in the excess cost of capital and (ii) the excess cost of capital is endogenously determined in equilibrium. The first extension shows that the regulated banking sector will shrink when the safe rate is low and the excess cost of bank capital is high. The second extension shows that bank capital regulation affects all financial intermediaries in the economy (both regulated and shadow banks) through its impact on the equilibrium cost of capital.

5.1 Changes in funding costs

We consider the effects of changing two key parameters of the model, namely the expected return required by investors R_0 (the safe rate) and the excess cost of bank capital δ, which may be linked, respectively, to the scarcity of debtholders' and shareholders' wealth. The results illustrate the implications of the model for the structure and risk of the financial system along the business cycle, as funding costs are a key variable that evolves with the cycle.

We first use the result in Proposition 1 to show the effects of changes in R_0 and δ on the marginal types of entrepreneurs $\widehat{p}_0$ and $\widehat{p}_1$ that are indifferent between market and bank finance under zero capital requirements and zero ($\eta=\eta_0=0$) and positive ($\eta=\eta_1>0$) certification costs. Differentiating (11) it is immediate to show that $\widehat{p}_0$ and $\widehat{p}_1$ are decreasing in the safe rate R_0, and increasing in the excess cost of bank capital δ. Hence, in the absence of regulation a decrease (increase) in the the safe rate R_0 (the excess cost of bank capital δ) results in an expansion of the range of entrepreneurs funded by the market.

We next analyze how the equilibrium structure of the financial system varies with funding costs in the presence of capital regulation. We find that for both types of capital requirements (flat and VaR based) a lower safe rate R_0 and a higher excess cost of bank capital δ expands the range of entrepreneurs financed by markets and shadow banks, and reduce range of entrepreneurs financed by regulated banks. According to these findings, our model predicts that, in the presence of capital requirements of either type, *the regulated banking sector will shrink and the unregulated sector* (markets and shadow banks) *will expand when the safe rate is low and the excess cost of bank capital is high.*

Figure 9 shows how the equilibrium structure of the financial system varies when there is an increase in funding costs under (high) flat capital requirements. An increase in the safe rate R_0 (dashed lines) results in debt finance being more expensive, which increases banks' incentives to raise capital. Panel A shows how for those banks for which capital regulation is not binding (regulated and shadow banks) higher safe rates increase their capital, while for those banks for which the regulation is binding capital remains unchanged. We can also observe how, given the higher incentives to raise capital, the set of entrepreneurs financed by banks (regulated and shadow) expands. Panel B shows how an increase in the safe rate results in a lower probability of default for all loans financed by banks. For those banks for which the capital requirement is binding, the effect is explained by the increase in loan rates and spreads, which increases screening incentives and lowers the probabilities of default.

Figure 9 (dotted lines) also shows how an increase in the excess cost of capital δ affects the equilibrium structure of the financial system. Panel A shows how for those banks for which capital regulation is not binding (regulated and shadow banks) a higher excess cost of bank capital reduces their capital, while for those banks for which the regulation is binding capital remains unchanged. This leads to a reduction in the set of entrepreneurs financed by banks. Panel B shows the differential effects on probabilities of default: entrepreneurs that move out of the regulated banking system increase in their probability of default, whereas those that remain with the regulated banks have mixed results. Those funded by regulated banks with no capital buffers see a reduction in the probability of default, due to the higher screening incentives associated with higher loan rates. However, for entrepreneurs funded by banks with capital buffers (both regulated and shadow banks), the increase in the cost of capital translates into an increase in the probability of default, due to the lower screening incentives associated with lower capital buffers. Hence, a change in the excess cost of capital has a differential impact on the probability of failure of financial institutions overall, reducing the probability of failure of those institutions for which the regulation is binding but increasing that of institutions with capital buffers.

[FIGURE 9]

Figure 10 shows how the equilibrium structure of the financial system varies when there is an increase in funding costs under (high) value-at-risk based capital requirements. As in the previous case, an increase in the safe rate R_0 (dashed lines) results in higher incentives to raise capital. Panel A shows how higher safe rates increase the capital of banks for which regulation is not binding, but reduce it for those for which it is binding. This expands the set of entrepreneurs financed by banks. It is relevant to highlight that given a VaR constraint, when safe rates go up banks have more incentives to screen borrowers, which reduces capital requirements.[21] Panel B shows how higher safe rates result in lower probabilities of failure for those banks for which the regulation is binding, but have no effect for those banks for which the regulation is binding.[22]

Figure 10 (dotted lines) shows how an increase in the excess cost of capital δ affects the equilibrium structure of the financial system. Panel A shows how, by reducing the incentives to raise capital, banks for which regulation is not binding react to a higher cost of capital by reducing their capital, which translates (see Panel B) into an increase in their probability of failure. This leads to a reduction in the set of entrepreneurs financed by banks.

[21] Notice that $\overline{k}_p$ in (15) is decreasing in R_0.

[22] Notice that when the regulation is binding the probability of failure is, by construction, equal to α.

[FIGURE 10]

Finally, we analyze how the optimal capital requirements characterized in Section 4.2 vary with the safe rate R_0 and excess cost of bank capital δ. Figure 11 shows the results. An increase in R_0 leads to higher optimal capital requirements, an expansion of the range of intermediated finance, and consequently a safer financial system. This effect is explained by the fact that the increase in R_0, for a given δ, reduces the relative cost of bank capital. Not surprisingly, an increase in the excess cost of capital δ leads to the opposite effects, reducing optimal capital requirements and the range of intermediated finance, and increasing the risk of the financial system. These results provide a rationale for the cyclical adjustment of capital requirements. In particular, when capital is scarce and the cost of capital is high, the requirements should be lowered; see Repullo (2013).

[FIGURE 11]

5.2 Endogenous cost of capital

We next consider the implications of replacing an exogenous by an endogenous excess cost of capital δ, determined by the intersection of an exogenous supply of bank capital $\overline{K}$ with a downward sloping demand for bank capital $K(\delta)$, derived from our previous analysis. In this case, bank capital regulation affects all financial intermediaries in the economy and not only the ones directly affected by the regulation, as was the case with an exogenous cost of capital. More specifically, entrepreneurs funded by regulated banks with capital buffers and entrepreneurs funded by shadow banks are also affected by changes in capital requirements through its impact on the equilibrium cost of capital. Thus, we identify spillover effects of regulation across the whole spectrum of regulated and shadow banks, even in the absence of direct linkages between them.

Following Holmström and Tirole (1997), suppose that there is fixed aggregate supply of bank equity capital $\overline{K}$.[23] As explained in the previous section, for any given bank capital

[23] Obviously, we could easily introduce an upward-sloping supply of bank capital. Depending on the assumed elasticity of the supply function, the results would be closer to the exogenous or the endogenous cost of capital setup.

regulation $\overline{k}_p$ and any given excess cost of capital δ there is a corresponding equilibrium investment x_p^* and capital k_p^* for regulated and shadow banks, so the aggregate demand for bank capital is given by

$$K(\delta) = \int_0^{\overline{p}} x_p^* k_p^* \, dp.$$

The equilibrium capital k_p^* for banks lending to entrepreneurs of type p is constrained to be at least $\overline{k}_p$ for regulated banks, is unconstrained (and lower than $\overline{k}_p$) for shadow banks, and it is equal to zero in case of direct market finance. By our previous results, an increase in the cost of capital δ expands the market finance and the shadow banking regions. Moreover, shadow banks and regulated banks with capital buffers will reduce their capital. Finally, the higher cost of capital for both regulated and shadow banks will translate into higher loan rates, and consequently by (17) lower aggregate investment. All in all, it follows that an increase in the cost of capital δ will reduce the aggregate demand for bank capital $K(\delta)$. The equilibrium cost of bank capital δ^* is obtained by solving the equation $K(\delta) = \overline{K}$.

A tightening of capital requirements (of either flat or Value-at-Risk based type) produces an upward shift in the demand for bank capital that increases the equilibrium cost of capital δ^*. While regulated banks for which the regulation is binding will be safer, regulated banks with buffers and shadow banks will have an incentive to save on costly capital, and hence they will be riskier. The indirect effect of tightening capital requirements through the equilibrium cost of capital may lead to overall increase in the risk of the financial system. Thus, it is not only that, as noted by Hanson, Kashyap, and Stein (2011), high requirements will drive a larger share of intermediation into the shadow banking realm (with lower capital and higher risk-taking), it is also the case that some regulated banks (those for which the regulation is not binding) and all shadow banks will be riskier.

We conclude that, with an endogenous cost of capital, tightening bank capital regulation has a negative effect on the risk-taking behavior of (regulated and shadow) banks that are not directly constrained by the regulation. This effect is a novel source of risk that should be taken into account when analyzing the costs and benefits of capital requirements.

6 Concluding Remarks

This paper proposes a framework to analyze the effects of bank capital regulation on the structure and risk of the financial system. The framework is built on the idea that financial intermediaries can reduce the probability of default of their loans by screening their borrowers at a cost. We assume that screening is not observed by debtholders, so there is a moral hazard problem. Intermediaries may be willing to use (more expensive) equity finance in order to ameliorate the moral hazard problem and reduce the cost of debt. The main novelty in the paper is that we assume that for this channel to operate, the capital structure has to be certified by an external (public or private) agent. Public certification is done by a bank supervisor that verifies whether those intermediaries that choose to be regulated (called regulated banks) comply with the regulation. Intermediaries that do not comply with the regulation (called shadow banks) have to resort to more expensive private certification.

We consider two different types of regulation, namely risk-insensitive (or flat) and risk-sensitive capital requirements, which broadly correspond to, respectively, the Basel I and Basel II and III Accords of the Basel Committee on Banking Supervision.[24] We show that regardless of the risk-sensitivity of the capital requirements, different types of financing can coexist. In particular, safer projects are always funded by the market, while riskier projects are funded by intermediaries. Depending on the risk-sensitivity of the requirements two different market structures can emerge. With flat requirements the equilibrium market structure is such that regulated banks always fund the riskiest projects, while if shadow banks operate they fund projects that are safer than those of the regulated banks. With risk-sensitive requirements the equilibrium market structure is such that regulated banks always fund the intermediate risk projects, while if shadow banks operate they fund the riskiest projects.[25]

[24] See Basel Committee on Banking Supervision (2015).

[25] Clearly, our setup can also serve to analyze a situation in which regulated banks can choose between standardized (less risk-sensitive) and VaR based (more risk-sensitive) requirements, as well as a situation in which banks are subject to both a (risk-insensitive) leverage ratio and (risk-sensitive) VaR based requirements.

We also examine a (more conventional) alternative to the certification story, in which the advantage of regulated banks relative to shadow banks comes from the existence of underpriced deposit insurances. Although the main results remain unchanged, there are some interesting differences. In particular, in the model with deposit insurance regulated banks never want to have capital buffers. Moreover, the shift from regulated to shadow banks may result in higher screening and lower default risk, while in the certification model it always results in lower screening and higher default risk.

The paper also contains a characterization of optimal capital requirements, which are less risk-sensitive than the those based on a Value-at-Risk criterion à la Basel II and III. It also discusses what happens when there are exogenous changes in the safe rate or in the cost of bank capital, showing that the regulated banking sector will shrink and the unregulated sector will expand when the safe rate is low and the excess cost of bank capital is high. Finally, it analyzes what happens when we endogenize the cost of capital, showing that in this case a tightening of capital requirements has a negative effect on the risk-taking behavior of (regulated and shadow) banks that are not directly constrained by the regulation, via the higher cost of bank capital.

We would like to conclude with three remarks. First, we have assumed that screening reduces the loans' probability of default, but we could also consider other effects on the quality of the pool of loan applicants, say reducing the loss given default. Second, although the model is set in terms of entrepreneurial finance it could also be interpreted in terms of household finance, with different types corresponding to say borrowers with different loan-to-values. Finally, it should be noted that reducing the gap between the costs of private and public certification, say by charging banks for the cost of bank supervision,[26] would lead to an expansion of the shadow banking system.

[26] In the US, neither the Federal Reserve System nor the Federal Deposit Insurance Corporation (FDIC) has directly assessed their supervised banks for the cost of supervisory oversight. The Fed's supervision expenses come out of the revenue generated from monetary policy operations, while the FDIC allocates a portion of deposit insurance premiums for operations, including supervision. In contrast, the European Central Bank charges supervisory fees that amounted to €425 million in 2017.

Appendix

A Deposit Insurance

This Appendix shows that our main qualitative results remain unchanged when we replace the assumption that private certification of capital (of shadow banks) is costlier than public certification (of regulated banks) by the assumption that regulated banks (but not shadow banks) are able to raise insured deposits with an underpriced deposit insurance premium that is normalized to zero. In our original setup, shadow banks enter the market when the higher cost of resorting to private certification is compensated by the lower cost of not complying with the regulation. In this setup, shadow banks enter the market when the lower cost of insured deposits is compensated by the lower cost of not complying with the regulation.

Clearly, the equilibrium loan rate R_p^* for entrepreneurs of type p under direct market finance will be the rate that satisfies the participation constraint (6). Similarly, the equilibrium loan rate R_p^* for entrepreneurs of type p under shadow bank finance will be the minimum rate that satisfies the bank's incentive compatibility constraint (7), the shareholders' participation constraint (8), and the investors' participation constraint (9) for a certification cost $\eta = 0$. So the only loan rate that needs to be determined is the one corresponding to the regulated banks.

One important difference with the model with certification costs is that with underpriced deposit insurance the capital constraint for the regulated banks is always binding. To see this, notice that with deposit insurance the investors' participation constraint (9) becomes $B_p^* = R_0$. Substituting this result into the first-order condition (12) gives

$$R_p^* - (1 - k_p^*)R_0 = c'(s_p^*). \tag{18}$$

Substituting this expression into the shareholders' participation constraint gives

$$(1 - p + s_p^*)c'(s_p^*) - c(s_p^*) = (R_0 + \delta)k_p^*. \tag{19}$$

Differentiating this expression we get

$$\frac{ds_p^*}{dk_p^*} = \frac{R_0 + \delta}{(1 - p + s_p^*)c''(s_p^*)} > 0.$$

Finally, differentiating (18) we conclude

$$\frac{dR_p^*}{dk_p^*} = -R_0 + c''(s_p^*)\frac{ds_p^*}{dk_p^*} = \frac{R_0(p - s_p^*) + \delta}{1 - p + s_p^*} > 0.$$

Since R_p^* is increasing in k_p^*, contestability implies that regulated banks will choose the lowest possible capital that complies with the regulation, that is $k_p^* = \bar{k}_p$. The intuition is that with deposit insurance regulated banks have no incentive to have capital buffers, since they would have no effect on their borrowing costs.

Substituting $k_p^* = \bar{k}_p$ into (19) and solving for s_p^* gives the equilibrium screening intensity of regulated banks lending to entrepreneurs of type p, and from here (18) gives the equilibrium loan rate R_p^*.

In the case of a flat capital requirement we would have that $\bar{k}_p = \bar{k}$ for all p, while in the case of a VaR based requirement $\bar{k}_p$ would be given by (15). Figures 12 and 13 show the equilibrium structure and the risk of the financial system under flat and VaR based capital requirements. We focus on the case of high requirements in order to show when shadow banks enter the market. As in the certification model, high flat (VaR based) capital requirements move intermediate (high) risk entrepreneurs to shadow banks. In contrast to the certification model, the probability of default of entrepreneurs funded by regulated banks need not be lower than the one that would obtain in a laissez-faire economy (with no capital regulation and no deposit insurance), since without deposit insurance banks could choose to have a higher level of capital than the one required by the regulation.

[FIGURES 12-13]

Thus, our qualitative predictions regarding the emergence of shadow banks when capital requirements tighten are robust to changing the nature of the positive effects of being subject to minimum capital regulation, from lower certification costs to lower cost of deposit funding via deposit insurance. In both cases the nature of the shadow banks that appear with stricter requirements depend on the exact form of regulation, with flat (VaR based) requirements inducing the entry in the financial system of intermediate (high) risk shadow banks.

B Proofs

Proof of Proposition 1 Suppose that the equilibrium screening intensity s_p^* satisfies $s_p^* \in (0, p)$. Then, by the convexity of the screening cost function $c(s_p)$, the bank's incentive compatibility constraint (7) reduces to the first-order condition (12).

To show that in this case the investors' participation constraint (9) is binding, note that if it were not we could slightly reduce the borrowing rate B_p^* and the loan rate R_p^* so that (12) would hold for the same s_p^*, in which case the shareholders' participation constraint (8) would still be satisfied, which contradicts the definition of equilibrium. To show that the shareholders' participation constraint (8) is also binding, note that if it were not we could slightly increase the bank's capital k_p^* and reduce the loan rate R_p^* so that (12) would hold for the same s_p^*, in which case the investors' participation constraint (9) would still be satisfied, which contradicts the definition of equilibrium.

Solving for B_p^* in the investors' participation constraint (9) (written as an equality), substituting it into the first-order condition (12), and rearranging gives (14). Adding up the two participation constraints (8) and (9) (written as equalities) and rearranging gives

$$R_p^* = \frac{R_0 + (\delta + \eta) k_p^* + c(s_p^*)}{1 - p + s_p^*}. \tag{20}$$

Putting together (14) and (20) implies

$$\frac{(1 - k_p^*) R_0}{1 - p + s_p^*} + c'(s_p^*) = \frac{R_0 + (\delta + \eta) k_p^* + c(s_p^*)}{1 - p + s_p^*}.$$

This equation shows the combinations of capital k_p^* and screening s_p^* that satisfy the incentive compatibility constraint (7) and the participation constraints (8) and (9) for the case where $0 < s_p^* < p$. Solving for k_p^* in this equation gives (13). By the properties of the screening cost function $c(s_p)$ we have $c'(s_p^*) = c(s_p^*) = 0$ for $s_p^* = 0$, and $s_p^* c'(s_p^*) > c(s_p^*)$ for $s_p^* > 0$. This implies that $s_p^* > 0$ if and only if $k_p^* > 0$.

The equilibrium loan rate R_p^* is given by

$$R_p^* = \min_{s_p, k_p} \left[\frac{(1 - k_p) R_0}{1 - p + s_p} + c'(s_p) \right] \tag{21}$$

subject to (13). The first-order condition that characterizes the solution to this problem is

$$\frac{dR_p^*}{ds_p^*} = -\frac{(1-k_p^*)R_0}{(1-p+s_p^*)^2} + \frac{(\delta+\eta)c''(s_p^*)}{R_0+\delta+\eta} = 0. \tag{22}$$

The second-order condition is

$$\frac{d^2R_p^*}{d(s_p^*)^2} = \frac{R_0}{(1-p+s_p^*)^3}\left[\frac{(1-p+s_p^*)^2c''(s_p^*)}{R_0+\delta+\eta} + 2(1-k_p^*)\right] + \frac{(\delta+\eta)c'''(s_p^*)}{R_0+\delta+\eta} > 0,$$

which holds by our assumptions on the screening cost function $c(s_p)$.

Notice that the first-order condition (22) implies

$$\left.\frac{dR_p^*}{ds_p^*}\right|_{s_p=k_p=0} = -\frac{R_0}{(1-p)^2} + \frac{(\delta+\eta)c''(0)}{R_0+\delta+\eta} < 0$$

if and only if $p > \widehat{p}$, where $\widehat{p}$ is defined in (11). From here it follows that riskier entrepreneurs of types $p > \widehat{p}$ will borrow from banks, while safer entrepreneurs of types $p \leq \widehat{p}$ will borrow from the market. Note that $\widehat{p} < 1$, and since $\widehat{p}$ is increasing in η assumption (10) ensures that $\widehat{p} > 0$.

It only remains to show that $s_p^* < p$. Since $s_p^* = 0$ for $p = \widehat{p}$, it suffices to show that $ds_p^*/dp < 1$ for $p > \widehat{p}$. Differentiating the first-order condition (22) taking into account (13) gives

$$\frac{ds_p^*}{dp} = \frac{2(\delta+\eta)(1-p+s_p^*)c''(s_p^*) + R_0c'(s_p^*)}{(\delta+\eta)\left[2(1-p+s_p^*)c''(s_p^*) + (1-p+s_p^*)^2c'''(s_p^*)\right] + R_0(1-p+s_p^*)c''(s_p^*)},$$

which implies the result given that $c''(s_p^*) > 0$, $c'''(s_p^*) > 0$, and $s_p^*c''(s_p^*) > c'(s_p^*)$ by the properties of the screening cost function $c(s_p)$. □

References

Acharya, V., Schnabl, P., and G. Suarez (2013) "Securitization without Risk Transfer," *Journal of Financial Economics*, 107, 515-536.

Admati, A. (2014), "The Compelling Case for Stronger and More Effective Leverage Regulation in Banking," *Journal of Legal Studies*, 43, s35 - s61.

Admati, A., and M. Hellwig (2013), *The Bankers' New Clothes*, Princeton University Press.

Adrian, T., and H. Shin (2014), "Procyclical Leverage and Value-at-Risk," *Review of Financial Studies*, 27, 373-403.

Basel Committee on Banking Supervision (2015), "A Brief History of the Basel Committee."

Beguenau, J., and T. Landvoigt (2017) "Financial Regulation in a Quantiative Model of the Modern Banking Sytem", mimeo.

Boissay, F., F. Collard, and F. Smets (2016), "Booms and Banking Crises," *Journal of Political Economy*, 124, 489-538.

Bolton, P., T. Santos, and J. Scheinkman (2016), "Savings Glut and Financial Fragility," https://ssrn.com/abstract=2743700.

Buchak, G., G. Matvos, T. Piskorski, and A. Seru (2017) "Fintech, Regulatory Arbitrage, and the Rise of Shadow Banks," Chicago Booth Working Paper.

Fahri, E., and J. Tirole (2017) "Shadow Banking and the Four Pillars of Traditional Financial Intermediation," NBER Working Paper No. 23920.

Financial Stability Board (2013), "Policy Framework for Strengthening Oversight and Regulation of Shadow Banking Entities."

Financial Stability Board (2018), "Global Shadow Banking Monitoring Report 2017."

Gordy, M., E. Heitfield, and J. Wu (2015), "Risk-Based Regulatory Capital and the Basel Accords," in A. Berger, P. Molyneux, and J. Wilson (eds.), *The Oxford Handbook of Banking*, Second Edition, Oxford University Press, Chapter 23.

Grill, M., D. Kalyaeva, and C. Lambert (2018), "How Competition and Regulation Drive Bank and Investment Fund Risk Profiles and their Market Shares," European Central Bank, *Macroprudential Bulletin*, 5.

Hanson, S., A. Kashyap, and J. Stein (2011), "A Macroprudential Approach to Financial Regulation," *Journal of Economic Perspectives*, 25, 3-28.

Hanson, S., A. Shleifer, J. Stein, and R. Vishny (2015) "Banks as Patient Fixed-Income Investors," *Journal of Financial Economics*, 117, 449–469.

Harris, M., C. Opp, and M. Opp (2017), "Higher Capital Requirements, Safer Banks? Macroprudential Regulation in a Competitive Financial System," Wharton School Working Paper.

Hellmann, T., K. Murdock, and J. Stiglitz, 2000, "Liberalization, Moral Hazard in Banking, and Prudential Regulation: Are Capital Requirements Enough?," *American Economic Review*, 90, 147-165.

Helpman, E., O. Itskhoki, and S. Redding (2010), "Inequality and Unemployment in a Global Economy," *Econometrica*, 78, 1239-1283.

Holmström, B., and J. Tirole (1997), "Financial Intermediation, Loanable Funds, and the Real Sector," *Quarterly Journal of Economics*, 112, 663-691.

Irani, R., R. Iyer, R. Meisenzahl, and J.-L. Peydró (2018), "The Rise of Shadow Banking: Evidence from Capital Regulation," mimeo.

Koehn, M. and Santomero, A. M., (1980), "Regulation of Bank Capital and Portfolio Risk," *Journal of Finance*, 35, 1235-1244

Martinez-Miera, D. (2009), "Bank Capital Requirements, Competition and Bank Failure," mimeo.

Martinez-Miera, D., and R. Repullo (2017), "Search for Yield," *Econometrica*, 85, 351-378.

Moreira, A., and A. Savov (2017) "The Macroeconomics of Shadow Banking," *Journal of Finance* forthcoming.

Plantin, G. (2015), "Shadow Banking and Bank Capital Regulation," *Review of Financial Studies*, 28, 146-175.

Repullo, R. (2004), "Capital Requirements, Market Power, and Risk-Taking in Banking," *Journal of Financial Intermediation*, 13, 156-182.

Repullo, R. (2013), "Cyclical Adjustment of Capital Requirements: A Simple Framework," *Journal of Financial Intermediation*, 22, 608-626.

Repullo, R., and J. Suarez (2004), "Loan Pricing under Basel Capital Requirements," *Journal of Financial Intermediation*, 13, 496-521.

Rochet, J.-C., (1992), "Capital Requirements and the Behaviour of Commercial Banks," *European Economic Review*, 36, 1137-1170.

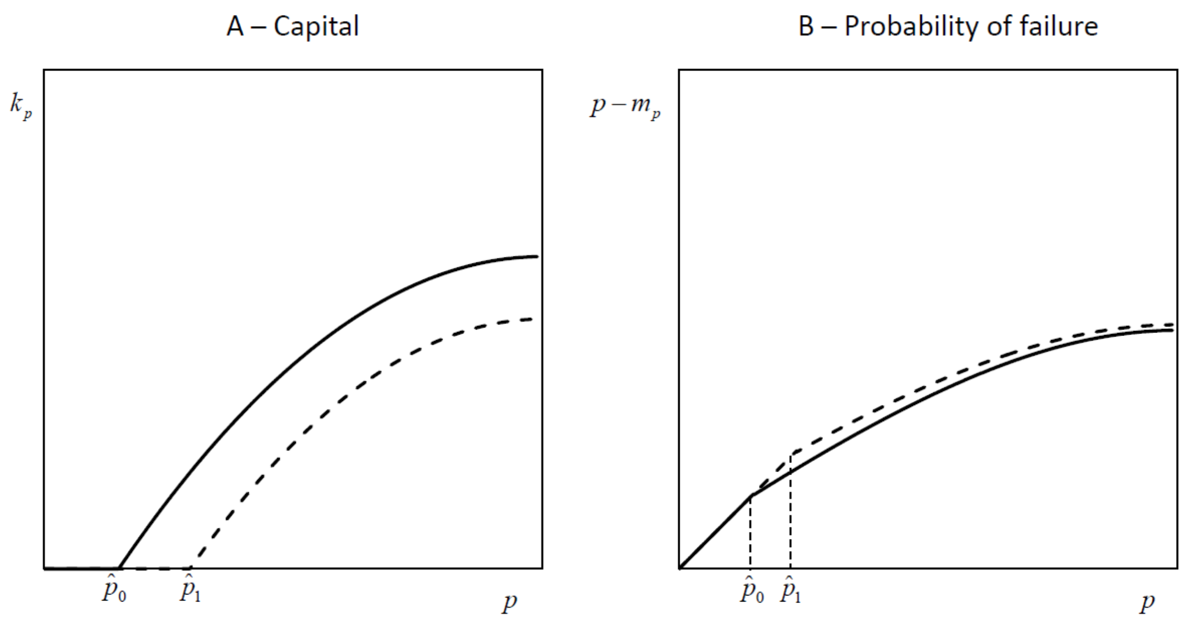

Figure 1. Public and private capital certification

This figure shows the equilibrium of the model with public and private capital certification. Panel A exhibits equilibrium capital and Panel B equilibrium probabilities of failure. Solid (dashed) lines represent equilibrium values with public (private) certification.

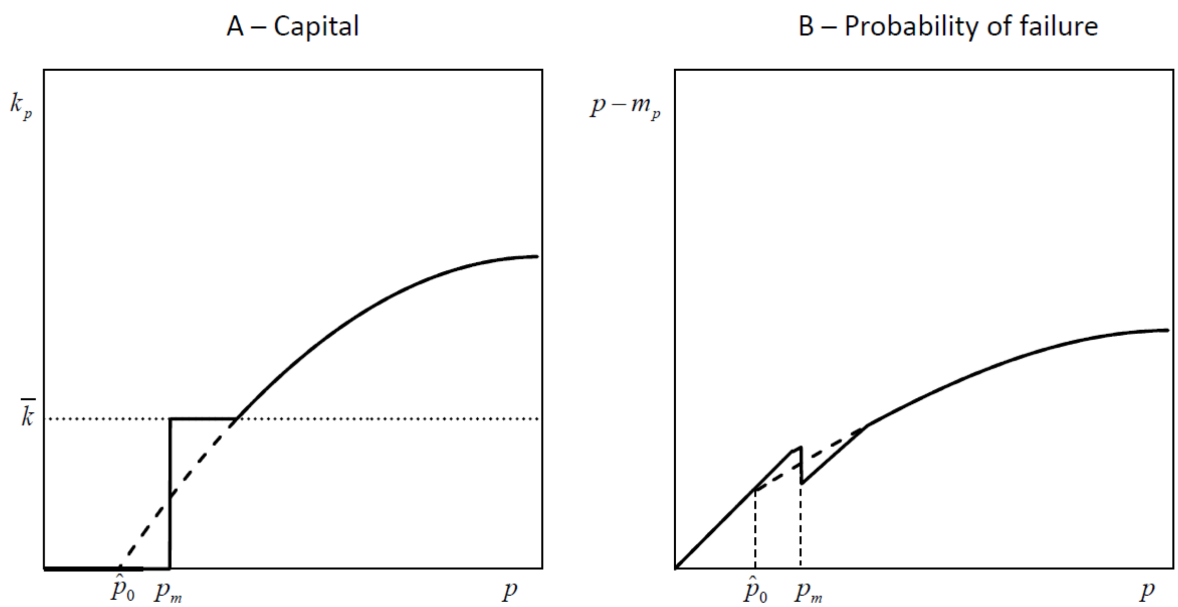

Figure 2. Low flat capital requirements

This figure shows the equilibrium of the model with low flat capital requirements. Panel A exhibits equilibrium capital and Panel B equilibrium probabilities of failure. Solid (dashed) lines represent equilibrium values with low (no) flat capital requirements.

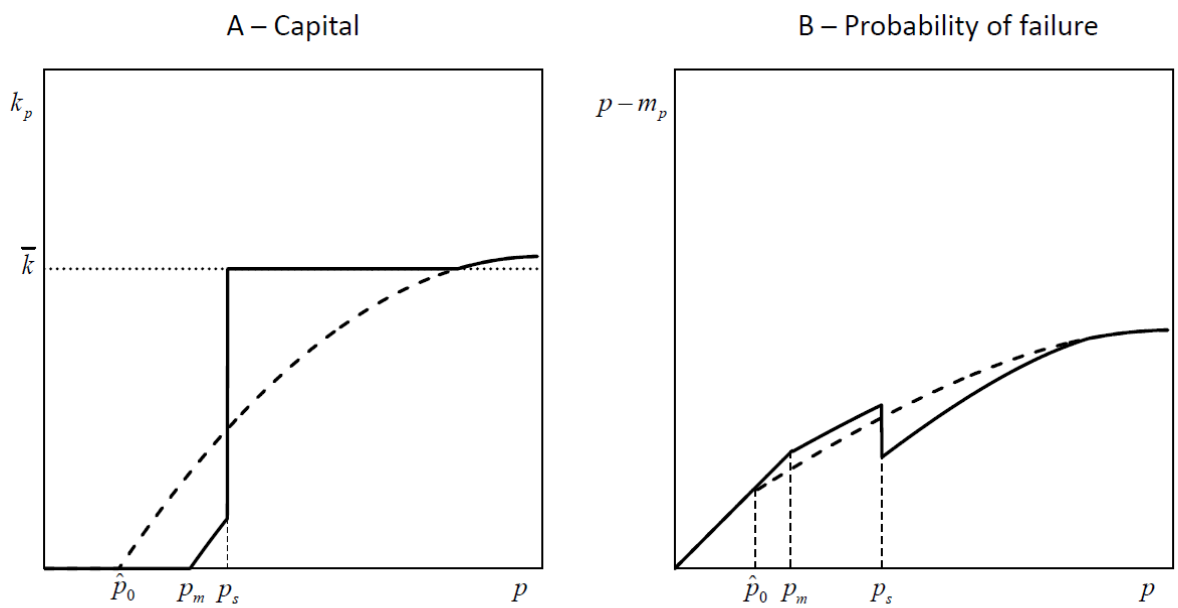

Figure 3. High flat capital requirements

This figure shows the equilibrium of the model with high flat capital requirements. Panel A exhibits equilibrium capital and Panel B equilibrium probabilities of failure. Solid (dashed) lines represent equilibrium values with high (no) flat capital requirements.

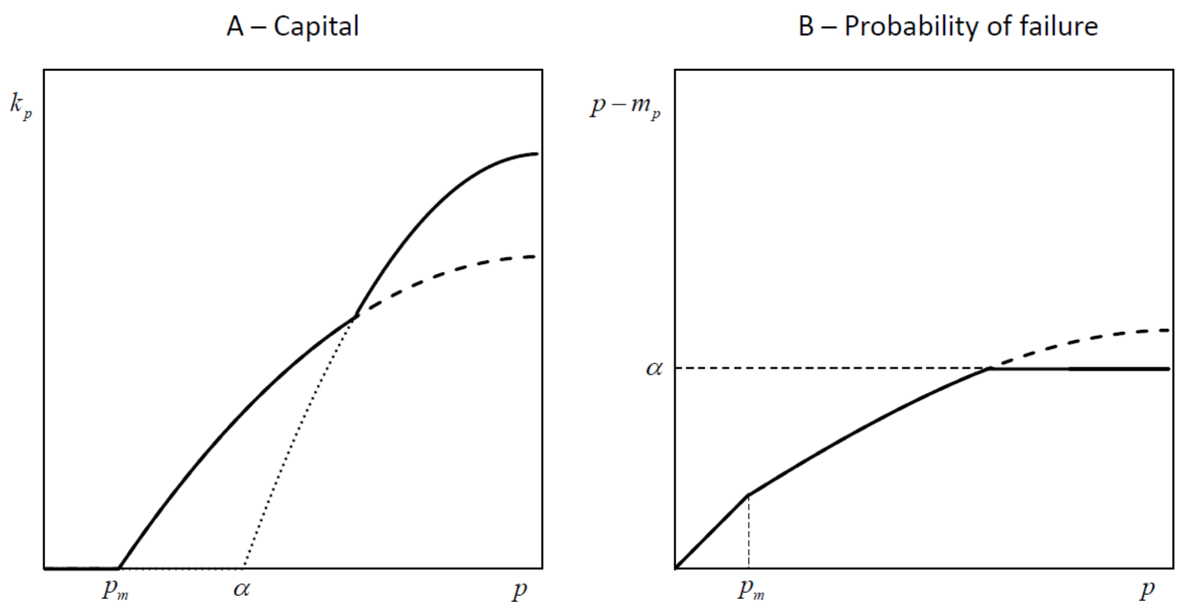

Figure 4. Low Value-at-Risk based capital requirements

This figure shows the equilibrium of the model with low Value-at-Risk based capital requirements. Panel A exhibits equilibrium capital and Panel B equilibrium probabilities of failure. Solid (dashed) lines represent equilibrium values with low (no) value-at-risk based capital requirements.

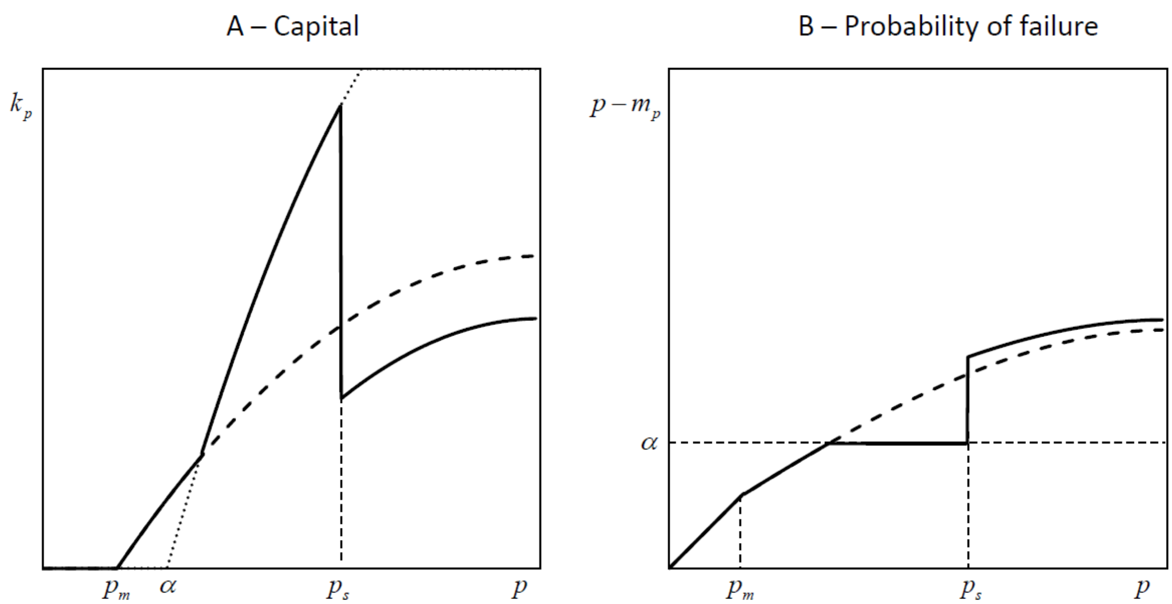

Figure 5. High Value-at-Risk based capital requirements

This figure shows the equilibrium of the model with high Value-at-Risk based capital requirements. Panel A exhibits equilibrium capital and Panel B equilibrium probabilities of failure. Solid (dashed) lines represent equilibrium values with high (no) value-at-risk based capital requirements.

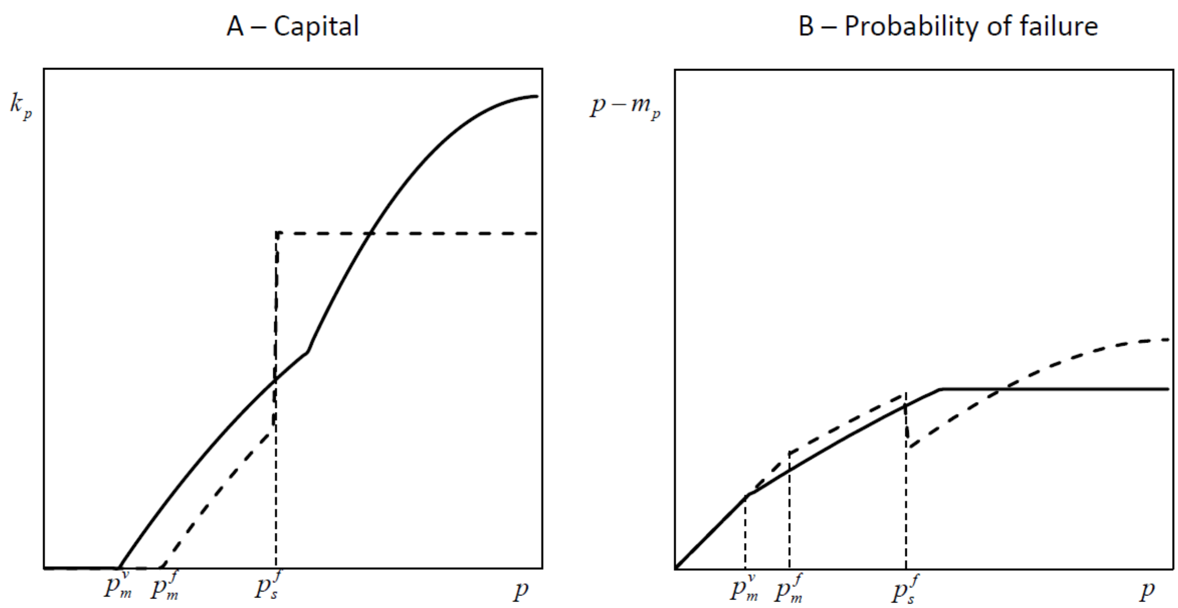

Figure 6. Optimal flat and Value-at-Risk based capital requirements

This figure shows the equilibrium of the model with optimal flat and Value-at-Risk based capital requirements. Panel A exhibits equilibrium capital and Panel B equilibrium probabilities of failure. Bold (dashed) lines represent equilibrium values with the optimal Value-at-Risk based (flat) capital requirements.

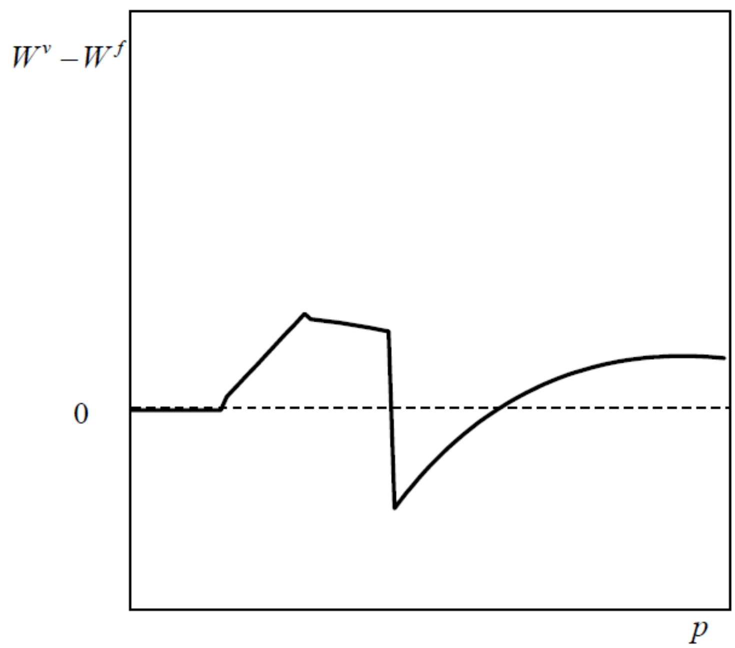

Figure 7. Welfare difference between optimal Value-at-Risk based and flat capital requirements

This figure shows the welfare difference between the optimal Value-at-Risk based and flat capital requirements corresponding to lending to the different types of entrepreneurs.

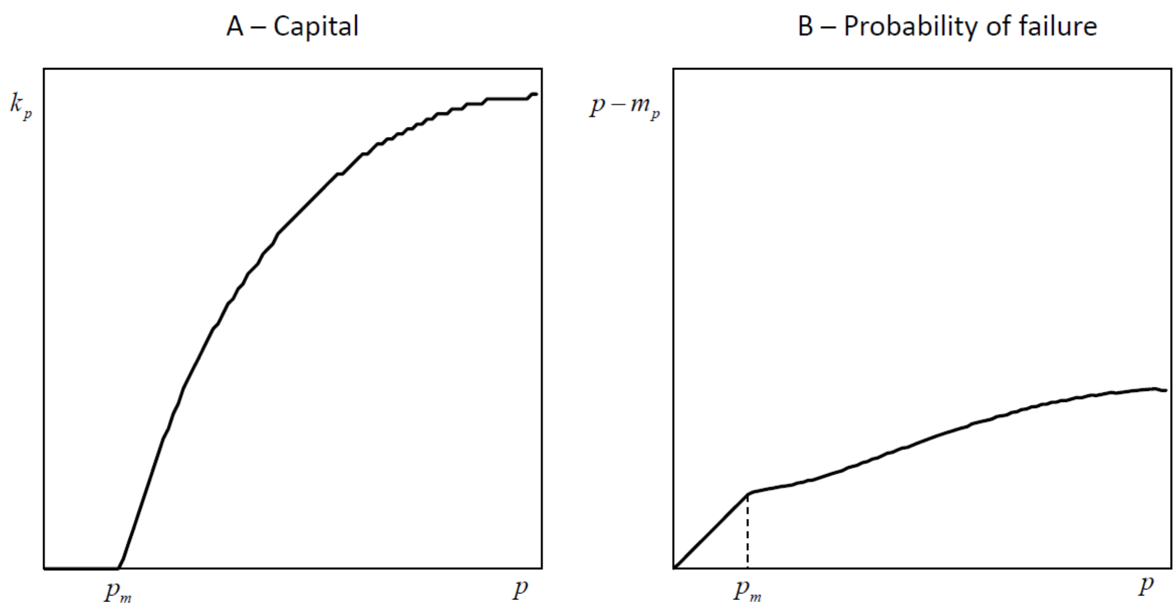

Figure 8. Optimal capital requirements

This figure shows the equilibrium of the model with optimal unconstrained capital requirements. Panel A exhibits equilibrium capital and Panel B equilibrium probabilities of failure.

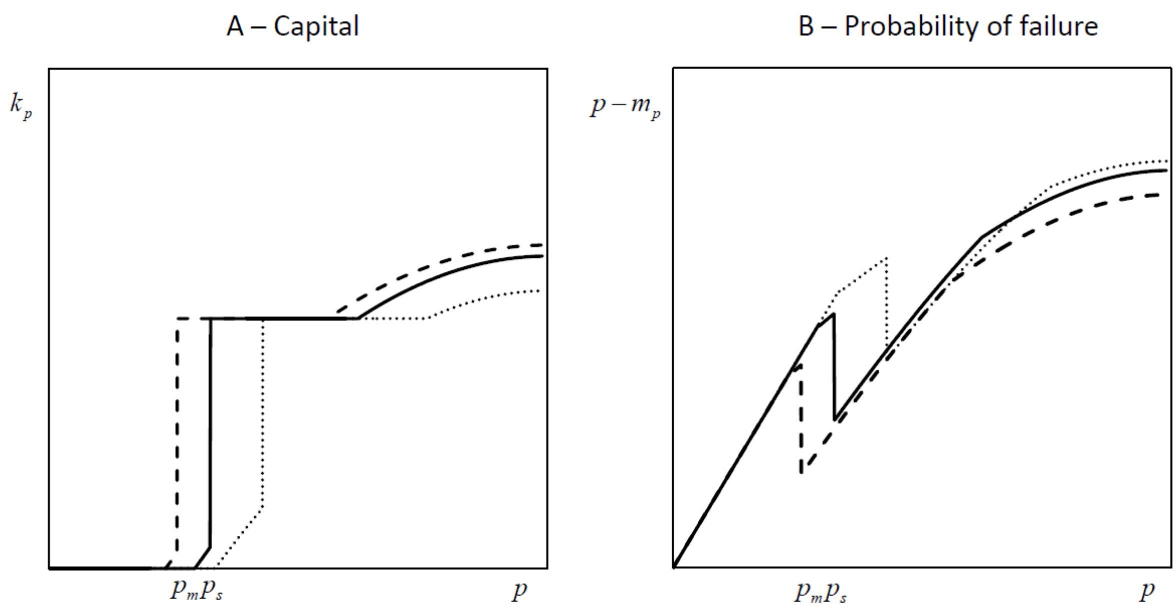

Figure 9. Changing funding costs with flat capital requirements

This figure shows the effect of changes in funding costs under flat capital requirements. Panel A exhibits equilibrium capital and Panel B equilibrium probabilities of failure. Dotted (dashed) lines represent equilibrium values with a higher excess cost of capital (safe rate). Bold lines represent the equilibrium before these changes.

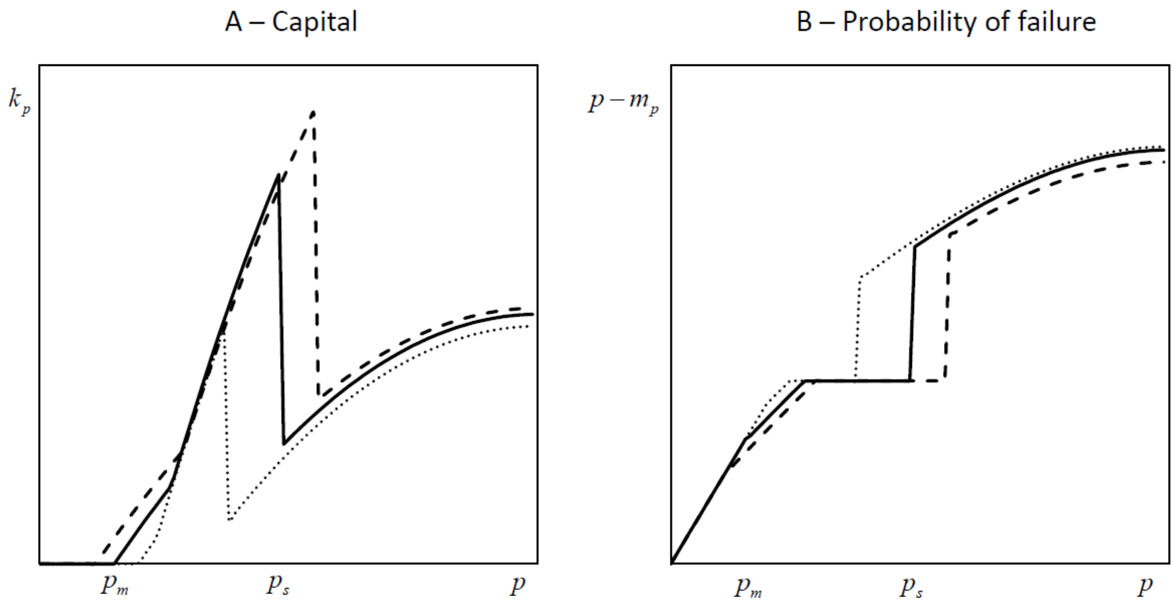

Figure 10. Changing funding costs with Value-at-Risk based capital requirements

This figure shows the effect of changes in funding costs under Value-at-Risk based capital requirements. Panel A exhibits equilibrium capital and Panel B equilibrium probabilities of failure. Dotted (dashed) lines represent equilibrium values with a higher excess cost of capital (safe rate). Bold lines represent the equilibrium before these changes.

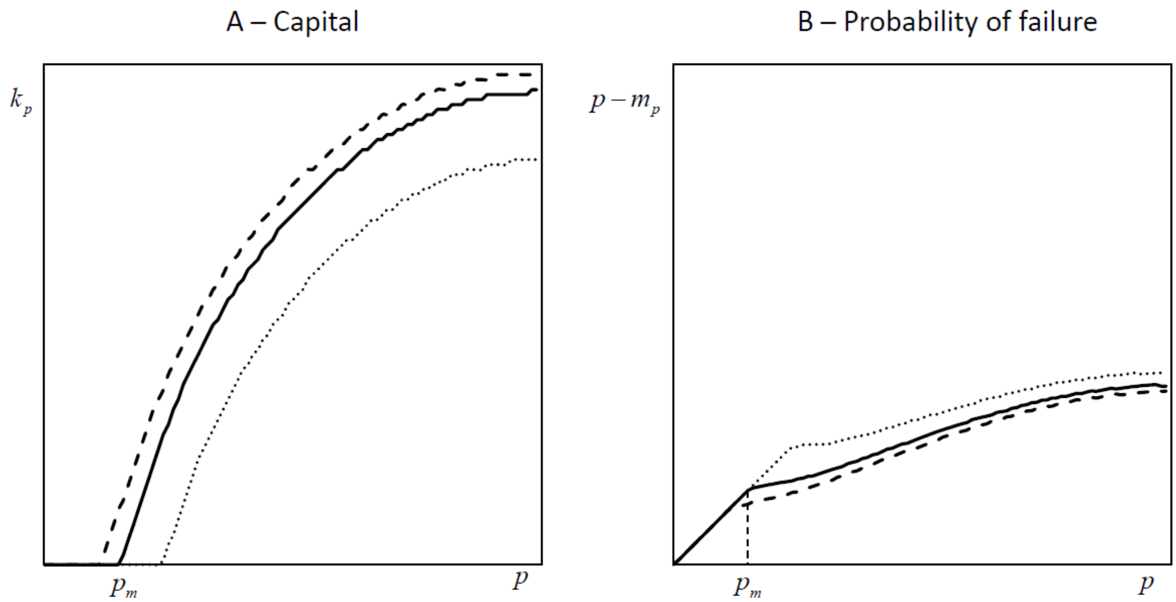

Figure 11. Changing funding costs with optimal capital requirements

This figure shows the effect of changes in funding costs under optimal unconstrained capital requirements. Panel A exhibits equilibrium capital and Panel B equilibrium probabilities of failure. Dotted (dashed) lines represent equilibrium values with a higher excess cost of capital (safe rate). Bold lines represent the equilibrium before these changes.

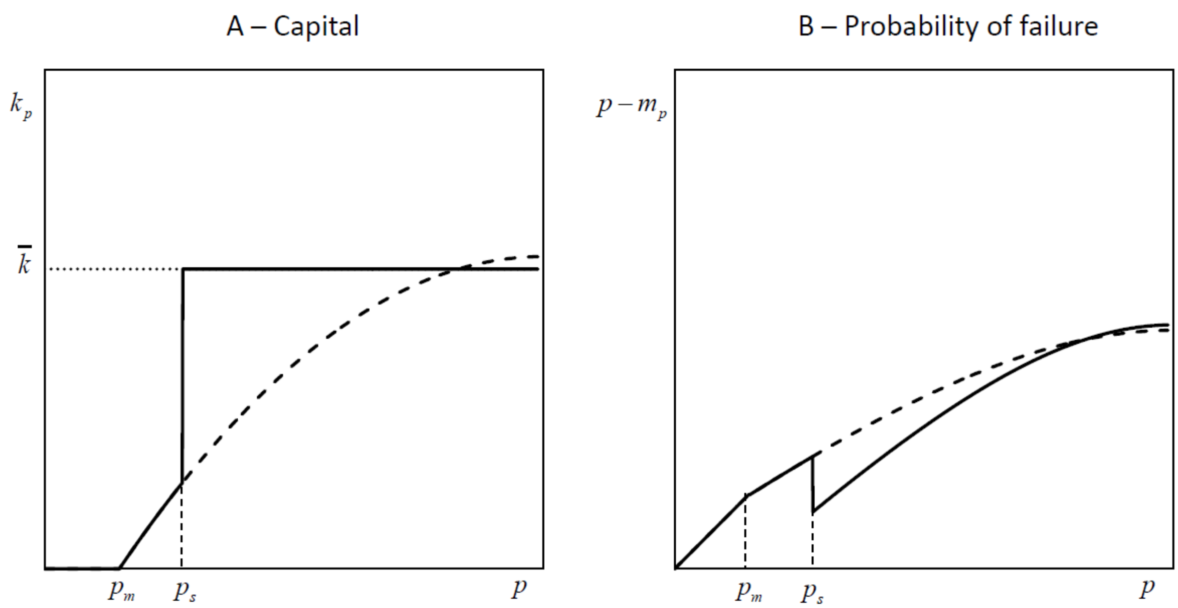

Figure 12. Flat capital requirements with deposit insurance

This figure shows the equilibrium of the model with (high) flat capital requirements and deposit insurance. Panel A exhibits equilibrium capital and Panel B equilibrium probabilities of failure. Solid (dashed) lines represent equilibrium values with (without) flat capital requirements and deposit insurance.

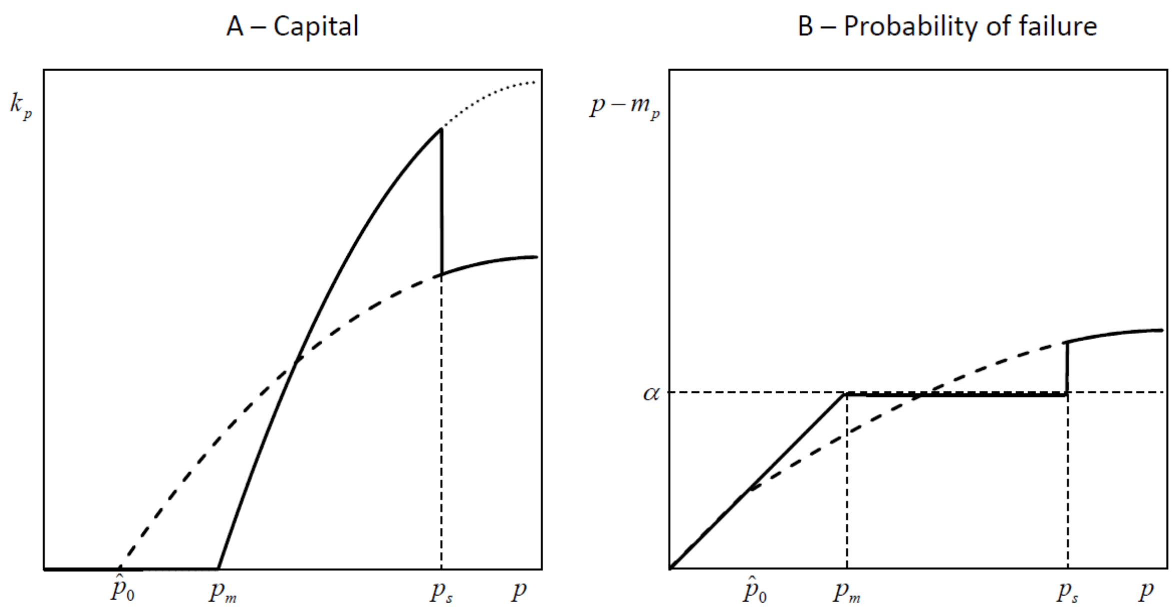

Figure 13. Value-at-Risk based capital requirements with deposit insurance

This figure shows the equilibrium of the model with (high) Value-at-Risk based capital requirements and deposit insurance. Panel A exhibits equilibrium capital and Panel B equilibrium probabilities of failure. Solid (dashed) lines represent equilibrium values with (without) Value-at-Risk based capital requirements and deposit insurance.