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Author: Diemo Dietrich Achim Hauck<ce:footnote id="fn0005"><ce:note-para id="npar0015">Tel.: +44 2392 84 4244.</ce:note-para></ce:footnote>

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Highlights

- Bank loan contracts specify the use of funds by the borrowing firm.
- The more funds are directed to tangible assets, the less risky the loan will be.
- A less risky loan requires less bank capital which makes the loan less expensive.
- To save on financing costs, firms prefer highly tangible over productive assets.
- Bank capital regulation corrects for this incentive putting a lower limit on costs.

Bank Capital Regulation, Loan Contracts, and Corporate Investment*

Diemo Dietrich† Achim Hauck‡

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Abstract

This paper studies the link between bank capital regulation, bank loan contracts and the allocation of corporate resources across firms' different business lines. Credit risk is lower when firms write contracts that oblige them to invest mainly into projects with highly tangible assets. We argue that firms have an incentive to choose a contract with overly safe and thus inefficient investments when intermediation costs are increasing in banks' capital-to-asset ratio. Imposing minimum capital adequacy for banks can eliminate this incentive by putting a lower bound on financing costs.

Keywords Financial contracting; Corporate investment; Asset tangibility; Bank capital regulation

JEL Classification G21, G28, G31

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†Corresponding author: Newcastle University Business School, 5 Barrack Road, Newcastle upon Tyne, NE1 4SE, United Kingdom, phone: +44 191 208 1564, email: diemo.dietrich@newcastle.ac.uk

‡University of Portsmouth, Portsmouth Business School, Richmond Building, Portland Street, Portsmouth, PO1 3DE, United Kingdom, phone: +44 2392 84 4244, email: achim.hauck@port.ac.uk

1 Introduction

To obtain external finance for corporate investments, non-financial firms often rely on banks. These financial institutions are special in two respects. First, they lower agency costs associated with financial relationships, and thus improve the allocation of capital and risks. They do so by offering loan and deposit contracts, which in essence represents a transformation of the financial contract in a direct financial relationship (Diamond, 1984; Diamond and Dybvig, 1983). Second, banks are subject to specific rules of regulation, especially with respect to bank capital.

Both aspects have been subject to extensive research on their own. Their interactions, however, are relatively unexplored. The regulation literature typically derives the need to regulate bank capital from agency problems at the banks' level; a particular focus lies on banks' incentive to take excessive risks via asset substitution and risk shifting.[1] This incentive stems from the debt-like nature of bank liabilities in combination with limited liability, or from a lack of market discipline due to the existence of an implicit or explicit safety net provided for banks and bank creditors. Accordingly, this research considers bank capital regulation as an instrument to improve the stability of banks by fostering an efficient allocation of risks, putting the incentives for banks right, and providing for optimal buffers against losses (Repullo and Suarez, 2013). With its focus on banks' incentives, these studies largely abstract from the function of banks to transform contracts and thus from potential effects of minimum capital requirements on the agency problems at the firms' level, i.e. on the behavior of bank-financed firms.

The objective of this paper is to explore how the behavior of bank-financed firms is linked to bank capital regulation. It focuses on the influence of minimum capital requirements on the terms of the loan contract between a bank and its corporate customers and how the latter use financial resources. To this end, we combine insights into the determinants of the cost

[1] See the surveys of Santos (2001), and VanHoose (2007)

and availability of bank credit from two distinct angles. One is that they are affected by bank capital regulation. The other is that they are also linked to the liquidity of assets held by firms.

To understand the influence of bank capital regulation on corporate investment and financing decisions, we study a model in which a firm with two investment projects faces a trade-off between allocative efficiency and financing costs. This trade-off emerges because the projects differ with respect to their liquidation values. By directing more resources to where they have a higher liquidation value, the firm can lower credit risk. This allows the banker to issue less bank capital as a protection against credit defaults; she can refinance a larger part of the loan with deposits. If borrowing from a bank is cheaper the less (more) the loan is refinanced by bank capital (deposits), a higher investment share in business lines with high liquidation value will lower the firm's financing costs. This induces the firm to deviate from an efficient resource allocation and to forgo investment returns in order to save on financing costs. A minimum capital-to-asset ratio for banks can mitigate this inefficiency by putting a lower bound on financing costs. We shall emphasize that, although pointing out an additional aspect for designing capital regulation, its normative implications are rather limited because of the paper's narrow focus.

Our analysis has several empirical implications which have not been tested yet. Among them, one is that banks with a larger capital basis should be expected to lend to customers with fewer tangible assets. Furthermore, in absence of a suitable bank capital regulation scheme, investments of bank financed firms will tend to be more biased towards highly liquid assets than possibly needed to secure access to external finance. This pattern should translate into a lower expected liquidation value of corporate assets the tighter capital standards are.

The theoretical backbones of our argument are taken from two complementary branches of the literature. Both are born out of the incomplete financial contracting approach based on the inalienability of human capital, relying on the notion that asset returns are non-verifiable and that firms cannot commit to contribute their human capital to their assets (Hart and Moore, 1994). According to this view, the willingness of financiers to lend out funds is a function of the value of physical assets when the firm actually withdraws the human capital so that the assets have to be liquidated. The first branch of the literature explores the link between corporate finance and investment in assets of different liquidation values. It argues that firms, who face a financial constraint, have a preference to commit themselves to invest primarily in assets with higher liquidation values as doing so eases their financial constraint (Dietrich, 2007; Almeida et al., 2011). We put this insight into perspective of a second branch, which delivers a microfounded theory of banks as financial intermediaries. It argues that the liquidation value of a firm can be improved when a bank with specific monitoring skills is deployed. However, these potential improvements are associated with a delegation cost. This cost arises because a bank can extract rents from investors by threatening to withdraw its specific skills. Unlike bank shareholders, depositors will punish any attempt to extract such a rent by running on the bank. Therefore, the delegation cost is the lower the more the bank is refinanced by deposits which implies, however, a higher vulnerability towards risks (Diamond and Rajan, 2000, 2001).

This approach is not the only possible way to account for the well established effect of capital regulation on the cost of financial services provided by banks. Equity capital for banks can have higher costs for several reasons (cf. Kashyap et al., 2008). Among them are measures taken by governments which discriminate equity finance against debt. Examples are tax systems and deposit insurance schemes that subsidize banks issuing deposits instead of equity capital. As argued in Peura and Keppo (2006) and Zhu (2008), raising equity capital can also be more costly than issuing debt because it takes more time and requires additional resources. Equity capital can also be more expensive when financial markets are subject to limited participation as in Holmström and Tirole (1997).[2] Although it is not crucial

[2]See Repullo (2004), and Allen et al. (2011), among others, for further applications of (privately) costly bank capital in analyzing bank capital regulation.

for our results why exactly the costs of financial services of banks are the larger the higher is their capital to asset ratio, our approach allows to investigate the link between banking and corporate finance in a consistent way. It is worth pointing out that the notion of higher cost of finance does not refer to the social cost of bank capital. Instead, our argument shares the view that the social cost of bank capital is smaller than the private cost, which justifies the regulation of banks' capital structure (Admati et al., 2010).

As for the proposed link between the value of assets to financiers and loan contract terms and volumes, recent empirical research confirms that this link is prevalent and relevant. First, external borrowing constraints are the tighter the less liquid the assets of firms are (Almeida et al., 2004; Almeida and Campello, 2007; Campello and Giambona, 2011). A second branch of empirical research shows that asset liquidation values determine not only investment, loan volumes and capital structure but even the terms of loan contracts. This refers to debt maturity (Benmelech, 2009), interest rates, duration and number of creditors (Benmelech et al., 2005), credit ratings, yield spreads, and loan-to-value ratios (Benmelech and Bergman, 2009) as well as overall cost of capital (Ortiz-Molina and Phillips, 2012). Most interestingly, Benmelech and Bergman (2009) provide indicative evidence that firms actively influence their terms of contracts by varying assets in a way that affects the overall asset valuation to financiers. They show that firms with higher default risk do not systematically pledge collateral of greater redeployability. This implies that lower default-risk firms possibly choose to have more deployable assets than required. Put differently, there seems to be leeway for firms to vary asset values to their own benefit.[3]

Our contribution to this literature is to show that the regulation of bank capital can have a distinct effect on firms' asset structure decisions. We also contribute to the literature on bank regulation by providing a new argument for why minimum capital requirements can be beneficial. As argued above, the majority of the banking literature focuses on how regulation

[3]This conclusion is furthermore supported by Graham (2000) and Graham and Harvey (2001) who find that firms—although possibly facing financial constraints—are typically underleveraged.

affects banks' default probabilities or banks' incentives to assume excessive risks via asset substitution and risk shifting. Our analysis explicitly abstracts from financial stability issues. Although there is no doubt on the relevance of these issues, turning them off sharpens the focus on the effects of bank regulation on the efficiency of firm-internal allocation decisions.[4] With our focus being different, we deliver an argument for why the effect of bank capital regulation on the cost and availability of funds to firms does not need to cause just worries about firms losing access to finance.

The paper is organized as follows. Section 2 discloses the assumptions that feed into the analysis. In section 3, we analyze the link between bank loan contracts, corporate investment, and bank capital structure, and how contracts will look like in absence of bank capital regulation. Section 4 shows that these contracts are associated with allocative inefficiencies and how bank regulation affects them. In section 5, we further discuss our results and their empirical implications. The final section summarizes our findings.

2 The model

Agents, endowments, and preferences. We consider an entrepreneur who is endowed with internal funds. They comprise any assets owned and controlled by the entrepreneur to be used for investment finance. Their total value is exogenous and denoted by $W > 0$. External funds can be provided by a large number of external financiers whose endowments sum up to at least 1 unit. There is also a banker who possesses no funds on her own. The banker serves as a financial intermediary between the entrepreneur and financiers. All agents are risk neutral. All assets, claims and liabilities are in real terms and valued in units of a single consumption good.

[4]With its focus on firm-internal allocation processes our paper is furthermore related to studies of internal capital markets, (e. g. Gertner et al., 1994; Hellwig, 2001; Stein, 2002; Almeida and Wolfenzon, 2006).

Technology. The entrepreneur operates a three-stage production technology that requires an initial funding of 1 unit. In the first stage (between dates t_0 and t_1), he (the entrepreneur) transforms the initial financial investment into one unit of an intermediate good. At t_1, this good has no value except for company-internal reinvestment in two business lines A and B. In the second stage of production (between t_1 and t_2) the entrepreneur uses the intermediate good in the two business lines to create assets (equipment, machinery etc.) which are necessary for the production of final goods. In the third stage (between t_2 and t_3), the entrepreneur produces the final goods. Let $I \in [0,1]$ denote the share of the intermediate good that has been reinvested in project A. Then, cash flows at t_3 are $R(I)$ for project A and $R(1-I)$ for project B, where R is a strictly increasing and concave function with $R'(0) = \infty$.[5] The first-best allocation that maximizes total returns $R(I) + R(1-I)$ is given by $I^{fb} = \frac{1}{2}$.

Specificity of human capital. As in Hart and Moore (1994), generating the cash flows requires the entrepreneur's specific skills. He is the only agent who knows how to market the final goods and how to appropriately adjust the production process or the characteristics of the products when market conditions change. Without the entrepreneur's human capital, the assets created through the reinvestment of the intermediate good have to be liquidated. Asset liquidation values are risky and differ across business lines. As for risk, we consider two possible states of nature. With probability p, the state s will be good, $s = g$, and the proceeds from liquidating assets at t_3 are moderate. With probability $1-p$, the state is bad, $s = b$, and proceeds from liquidation are considerably lower at t_3. In formal terms, the liquidation value of assets in state s is $\mu\beta_s I_s$ for business line A and $\beta_s(1-I_s)$ for business line B, with $\beta_g > \beta_b > 0$ and $\mu \geq 0$. Without loss of generality, the project with the lower liquidation value is henceforth called project A, i.e. μ is considered to be smaller than 1. The total

[5] Applying the same production function to both business lines is an innocent assumption, which is made to save on notational clutter.

liquidation value is $\Psi_s(I_s) := \mu\beta_s I_s + \beta_s(1-I_s)$. While the actual state is revealed only at t_1, all parties know the respective probabilities at t_0.[6]

Contractual environment. Financial contracts suffer from three types of frictions. Firstly, the entrepreneur can credibly threaten to withdraw his human capital at any date before t_3. It is only in the spot market that he can commit to contributing his human capital to the project. Secondly, project cash flows, the liquidation value of assets, and the state of nature are not verifiable. Thirdly, financiers are not able to directly control the allocation of the intermediate good between the two projects. Only a banker has the skills and means to monitor the use of resources and to enforce an allocation as laid down in a loan contract. While the first two frictions are directly adopted from Hart and Moore (1994), the third friction arises from Diamond and Rajan (2001).

Loan contract renegotiations. The frictions have several immediate implications, which are standard in the incomplete contracting literature. One is that loan contracts can specify the entrepreneur's repayment obligation H^* and the contractual allocation I^* in a non-contingent fashion only. Another implication is that the entrepreneur can renegotiate the terms of the contract at any date before completion of the projects at t_3. For those renegotiations we assume that the entrepreneur has full bargaining power. He can make a take-it-or-leave-it-offer to the bank, accompanied by a credible threat to withdraw his human capital if the banker declines the offer. We will denote the terms of the initially agreed upon contract at t_0 by H^* and I^* and the terms that are effective after potential renegotiations at t_1 by H_1^* and I_1^*. Accordingly, the contracts that are in place as from date t_0 and t_1 are henceforth denoted by the tuples $\langle H^*, I^* \rangle$ and $\langle H_1^*, I_1^* \rangle$, respectively. At t_2 the entrepreneur can renegotiate

[6]Results do not change when we consider the production technology also as stochastic as long as liquidation values and production outcomes are not perfectly correlated.

only his repayment obligation because the allocation I_s of the intermediate good has been implemented between t_1 and t_2 and is irrevocable at t_2.

Financial intermediation. At t_0, the banker refinances the loan by a mix of deposits and equity capital. If the banker failed to service depositors at t_3 and to pay them the initially agreed upon contractual face value D^* of deposits in full, she would default and the bank ceased to exist. Assuming that the banker wishes to avoid a default, she may have to refinance loans by a more flexible financial instrument. Bank capital (equity shares) is such an instrument. Its flexibility is costly, however: We assume that shareholders cannot force the banker to pay out everything; instead the banker and her shareholders always equally split the banker's loan earnings net of deposits D^*.[7]

Participation constraints and market structure. Investors compete for investment opportunities since profitable investment projects are considered to be scarce. Any safe alternative investment is assumed to generate a zero net return. Therefore, financiers are willing to refinance the bank when the expected repayment by the banker covers the opportunity costs of funding. Similarly, the banker assumes her function as a financial intermediary only if she expects to make a non-negative profit. Although there is only a single banker, the market for bank loans is contestable ex ante. The banker will thus offer a loan contract that maximizes the expected profit of the entrepreneur given that financiers and the banker are willing to participate. The outside option for the entrepreneur is sufficiently low such that he is willing to run his business as long as he can secure its financing.

Final profits. If the entrepreneur has not withdrawn his human capital in the course of his lending relationship with the banker, he will obtain the cash flows of the projects at t_3 and

[7] Note that these assumptions are not only consistent with the model setup. Diamond and Rajan (2000, 2001) have shown that they can be actually derived from first principles within an incomplete contracts framework like ours.

make some loan repayment H_s, so that his final profit is $\pi_s^e = R(I_s) + R(1 - I_s) - H_s - W$. The banker's final profit is $\pi_s^b = \frac{1}{2}(H_s - D)$ because she receives the loan repayment from the entrepreneur, repays the face value D of deposits and shares the remainder with capital holders.

Sequence of events. To conclude, Figure 1 summarizes the timing of the model.

Insert Figure 1 about here

3 Investment (in-)efficiency and financing costs

The model setup is meant to capture an important aspect of long-term debt: It is collateralized by the assets of the entrepreneur and the liquidation value of this collateral may change over the term of the loan. One reason for those changes is that the conditions, under which the assets can be deployed in their next-best use, are subject to volatility. The other reason is that there are times at which a borrowing firm has control over resources and the way how these resources are used will not only affect the overall productivity of the firm, but also the liquidation value of the firm's assets. In an effort to secure their potentially diverging interests, banks and firms make ex ante agreements on the loan repayment and on how resources will be used. However, these agreements can be subject to renegotiations.

In this section, we derive the terms of the initial loan contract $\langle H^*, I^* \rangle$ as negotiated in a sub-game perfect equilibrium of this dynamic game between the entrepreneur, the banker and financiers. We also investigate the implications of the initial loan contract for the bank's capital structure, the efficiency of the resource allocation, the loan repayment of the entrepreneur, and how renegotiations change the terms of the contract. We proceed in two major steps. First, for a given initial loan contract, we look into the changes of its terms over time due to renegotiations. Second, we identify the contract that the entrepreneur will prefer over all other contracts.

3.1 Amendments of loan contracts over time

We apply backward induction to determine how renegotiations between the entrepreneur and the banker change the terms of an initial agreement $\langle H^*, I^* \rangle$. At t_2, the entrepreneur can renegotiate the terms that have been effective since t_1. As the reinvestment I_s of the intermediate good has already been made before t_2 and is irrevocable, the entrepreneur can only renegotiate repayments by offering to repay $\tilde{H}_2$ instead of H_1^*. If the banker accepts, the entrepreneur will contribute his human capital to the projects and repay $\tilde{H}_2$ at t_3. If the banker rejects the offer, the contractual repayment obligation will remain unchanged. The entrepreneur will withdraw his human capital and the assets can merely be liquidated for $\Psi_s(I_s)$. The banker's actual earnings at t_3 will thus be $\min\{H_1^*, \Psi_s(I_s)\}$. Accordingly, the banker accepts an offer $\tilde{H}_2$ at t_2 if

$$\tilde{H}_2 \geq \min\{H_1^*, \Psi_s(I_s)\}. \tag{1}$$

As the entrepreneur will offer a repayment $\tilde{H}_2$ to maximize his final profit $\pi_s^e = R(I_s) + R(1 - I_s) - \tilde{H}_2 - W$ subject to (1), we obtain

Lemma 1. *For a given contract $\langle H_1^*, I_1^* \rangle$ that has been effective since t_1, renegotiations of its terms at t_2 in state s imply that the actual repayment of the entrepreneur to the banker at t_3 is* $\min\{H_1^*, \Psi_s(I_s)\}$.

Proof. Omitted. □

The liquidation value $\Psi_s(I_s)$ of assets determines the threat point of the banker in renegotiations at t_2. Accordingly, actual repayments of the entrepreneur at t_3 are bounded above by this liquidation value, which is higher, the lower has been the investment in project A.

As for renegotiations at t_1, the entrepreneur can propose to replace the initial loan contract $\langle H^*, I^* \rangle$. Let $\tilde{H}_1$ and $\tilde{I}_1$ denote the entrepreneur's new offer regarding repayment and allocation. If the banker agrees to replace the initial contract, the contract terms are changed to $H_1^* = \tilde{H}_1$ and $I_1^* = \tilde{I}_1$. The entrepreneur will implement the allocation $\tilde{I}_1$ between t_1 and t_2, and, according to Lemma 1, he will repay $\min\{\tilde{H}_1, \Psi_s(\tilde{I}_1)\}$ at t_3. If the banker rejects, the initial contract remains in place: the allocation is $I_s = I_1^* = I^*$ and the repayment obligation remains $H_1^* = H^*$. The entrepreneur will then repay $\min\{H^*, \Psi_s(I^*)\}$. Therefore, the banker accepts a new offer if

$$\min\{\tilde{H}_1, \Psi_s(\tilde{I}_1)\} \geq \min\{H^*, \Psi_s(I^*)\}, \tag{2}$$

implying that there is a lower bound for acceptable new repayment offers $\tilde{H}_1$ and an upper bound for acceptable new allocations $\tilde{I}_1$. In renegotiations at t_1, the entrepreneur makes an offer that maximizes his profit $\pi_s^e = R(\tilde{I}_1) + R(1 - \tilde{I}_1) - \min\{\tilde{H}_1, \Psi_s(\tilde{I}_1)\} - W$ subject to (2). This leads to

Lemma 2. *For a given initial contract $\langle H^*, I^* \rangle$, renegotiations of its terms at t_1 in state s imply that the actual repayment H_s of the entrepreneur to the banker at t_3 and the actual resource allocation I_s—implemented between t_1 and t_2—have the following properties*

$$H_s = \min\{H^*, \Psi_s(I^*)\}, \tag{3}$$

$$I_s = \min\left\{I^{fb}, I^* + \max\left\{\frac{\Psi_s(I^*) - H^*}{(1-\mu)\beta_s}, 0\right\}\right\}. \tag{4}$$

Proof. See Appendix. □

The entrepreneur will thus never offer to increase the repayment to the banker beyond H^*. When the initial agreement on the allocation I^* ensures that the entrepreneur does not default, so that $\Psi_s(I^*) \geq H^*$, the banker will insist on full repayment of H^* but is willing to let the entrepreneur invest more than I^* in project A as long as this does not reduce her threat point in later renegotiations below H^*. The entrepreneur either allocates the intermediate good efficiently, $I_s = I^{fb}$, or implements the least distorted allocation that is just acceptable for the banker. When $\Psi_s(I^*) < H^*$, the banker cannot prevent the entrepreneur from defaulting. Hence, she will not accept any increase in I_s beyond I^* as this would only further reduce what she can collect at t_3.

To sum up, the banker is more inclined to make concessions regarding investment if the initial repayment obligation H^* is low or if I^* is high. Moreover, when the state of the world is good, the liquidation value of projects is relatively high and gives the entrepreneur more leeway to renegotiate the investment pattern. Consequently, compared to the bad state, the good state tends to be associated with higher repayments of the entrepreneur and less investment inefficiencies.[8]

3.2 Terms of the initial loan contract

After having clarified the implications of renegotiations of any given initial loan contract $\langle H^*, I^* \rangle$, the next step is to characterize the terms of the loan contract as agreed upon at t_0 in a sub-game perfect equilibrium. As the market for bank loans is contestable ex ante, the entrepreneur could, in principle, apply for loans with different bankers, and he will accept the most attractive offer. Perfect competition among financiers ensures that they are indifferent between becoming a depositor or a shareholder. Hence, the expected returns for both types of financiers will be equal to the rate of return on their investment alternative.

[8] Note that it is not the banker who effectively chooses the allocation of resources but the entrepreneur, for whom the contract with the banker serves as a commitment device.

Formally, the initial loan contract shall solve the entrepreneur's optimization problem

$$\max_{H^*,I^*,D^*} E\left[\pi_s^e\right] = E\left[R\left(I_s\right) + R\left(1 - I_s\right)\right] - E\left[H_s\right] - W \tag{5}$$

s. t. (3), (4),

$$D^* \leq H_b, \tag{6}$$

$$D^* + \tfrac{1}{2}\left(E\left[H_s\right] - D^*\right) \geq 1 - W. \tag{7}$$

Equation (5) reflects the objective of the entrepreneur to maximize his expected profit, i. e. the expected total returns of projects less the expected actual loan repayment and the opportunity cost of internal funds. The restriction (6) stems from the unwillingness of the banker to default on deposits. This requires that the face value D^* of deposits is limited to what the banker can repay in the worst state, which is equal to the amount H_b that the entrepreneur repays in this state. Also, this condition ensures that the banker makes a non-negative expected profit at t_3 so that she is willing to grant a loan. The restriction (7) reflects the budget constraint of the banker. Since the value of the entrepreneur's internal funds is W and the banker possesses no funds on her own, she must raise a total of $1 - W$ from financiers, see the right hand side of (7). The banker will always fully service depositors so that the first term on the left hand side of (7) reflects the expected payoff of depositors. The remaining repayment of the entrepreneur will be equally split between shareholders and the banker. Accordingly, the second term on the left hand side reflects the expected payoff of shareholders.

To further clarify the optimization problem, it is useful to solve the budget constraint (7) for the expected loan repayment of the entrepreneur. For all $E\left[H_s\right] \geq D^*$, this yields

$$E\left[H_s\right] \geq 2\left(1 - W\right) - D^*. \tag{8}$$

Accordingly, the volume D^* of deposits establishes a lower bound on expected repayments and thus on the cost of external financing: The more the bank is financed by deposits (equity), the less (more) expensive the loan to the entrepreneur can be. Intuitively, every additional dollar of deposits makes one dollar of capital plus one dollar of banker's rents redundant so that minimum financing costs decrease by one dollar. In addition, we know from (3) and (4) that the actual repayment of the entrepreneur in the bad state, and thus the maximum volume of deposits, will be higher, the lower is the contractual allocation I^* of the intermediate good, which tends to lower investment efficiency. Combining both aspects establishes the central trade-off in this model: The lower is I^*, the lower are total project returns but the higher is the maximum volume of deposits, which lowers the minimum financing costs of the entrepreneur.

Solving the optimization problem and denoting the resulting optima by the subscript *eq* yields

Proposition 1. *Define*

$$\overline{W}\left(I^*\right) := 1 - \Psi_b\left(I^*\right), \tag{9}$$

$$\underline{W}\left(I^*\right) := 1 - \Psi_b\left(I^*\right) - \tfrac{p}{2}\left[\Psi_g\left(I^*\right) - \Psi_b\left(I^*\right)\right]. \tag{10}$$

Then, the entrepreneur can raise a loan if and only if $W > \underline{W}(0)$ and the sub-game perfect equilibrium has the following properties.

a) If $W \geq \overline{W}\left(I^{fb}\right)$, then

$$\begin{aligned} I^*_{eq} &= I^{fb}, & D^*_{eq} &= 1 - W, \\ I_b &= I^{fb}, & H^*_{eq} &= 1 - W, \\ I_g &= I^{fb}, & E\left[H_s\right] &= 1 - W. \end{aligned}$$

b) If $\overline{W}\left(I^{fb}\right) > W \geq \underline{W}\left(I^{fb}\right)$, then

$$\begin{aligned} I_{eq}^{*} &= \max\left\{\bar{I}, I^{B}\right\} < I^{fb}, & D_{eq}^{*} &= \Psi_b\left(I_{eq}^{*}\right), \\ I_b &= \max\left\{\bar{I}, I^{B}\right\} < I^{fb}, & H_{eq}^{*} &= 1 - W + \tfrac{2-p}{p}\left[\overline{W}\left(I_{eq}^{*}\right) - W\right], \\ I_g &= I^{fb}, & E\left[H_s\right] &= 1 - W + \left[\overline{W}\left(I_{eq}^{*}\right) - W\right]. \end{aligned}$$

c) If $\underline{W}\left(I^{fb}\right) > W > \underline{W}(0)$, then

$$\begin{aligned} I_{eq}^{*} &= \min\left\{\underline{I}, \max\left\{\bar{I}, I^{C}\right\}\right\} < I^{fb}, & D_{eq}^{*} &= \Psi_b\left(I_{eq}^{*}\right), \\ I_b &= \min\left\{\underline{I}, \max\left\{\bar{I}, I^{C}\right\}\right\} < I^{fb}, & H_{eq}^{*} &= 1 - W + \tfrac{2-p}{p}\left[\overline{W}\left(I_{eq}^{*}\right) - W\right], \\ I_g &= \min\left\{I^{fb}, \underline{I} + \tfrac{(2-p)\left[\Psi_b\left(I_{eq}^{*}\right) - \Psi_b\left(\underline{I}\right)\right]}{p(1-\mu)\beta_g}\right\}, & E\left[H_s\right] &= 1 - W + \left[\overline{W}\left(I_{eq}^{*}\right) - W\right], \end{aligned}$$

where $\bar{I}$ and $\underline{I}$ are implicitly defined by $W =: \overline{W}\left(\bar{I}\right)$ and $W =: \underline{W}\left(\underline{I}\right)$, respectively, and where I^{B} and I^{C} are implicitly defined by

$$(1-p)\left[R'\left(I^{B}\right) - R'\left(1 - I^{B}\right)\right] = (1-\mu)\,\beta_b, \tag{11}$$

$$(1-p)\left[R'\left(I^{C}\right) - R'\left(1 - I^{C}\right)\right] = (1-\mu)\,\beta_b + (2-p)\,\frac{\beta_b}{\beta_g}\left[R'\left(I_g\right) - R'\left(1 - I_g\right)\right]. \tag{12}$$

Proof. See Appendix. □

The entrepreneur wants to economize on financing costs. For this purpose, he will contract with a banker who refinances the loan to a large extent with deposits and issues only little bank capital. There is, however, an upper bound for both, deposits and capital. Intuitively, an agreement I^{*} on the allocation defines the banker's threat point for renegotiations at t_1 and t_2, which pinpoints the entrepreneur's maximum possible repayment for each state s. The resulting maximum repayment $\Psi_b\left(I^{*}\right)$ in the bad state constitutes the upper limit of deposits, while the maximum repayment $\Psi_g(I^*)$ in the good state limits the volume of additional bank capital to $\frac{p}{2}[\Psi_g(I^*) - \Psi_b(I^*)]$.

We can use these upper limits to define three regions in the (W, I^*)-plane (see (9), (10) and Figure 2). In the first region with $W \geq \overline{W}(I^*)$, the maximum volume of deposits $\Psi_b(I^*)$ covers the entrepreneur's financing gap $1 - W$ for a loan contract that stipulates I^*. In this *zero capital* region, the banker can fully refinance the loan by deposits. There is no need for bank capital so that rent extraction by the banker can be avoided. Accordingly, the minimum financing costs of the entrepreneur are $1 - W$. The second region is where $\overline{W}(I^*) > W \geq \underline{W}(I^*)$ and the maximum volume of deposits $\Psi_b(I^*)$ falls short of the entrepreneur's financing gap $1 - W$. Therefore, a bank loan with I^* requires partial refinancing with bank capital. This gives the banker some leeway to extract rents and increases the financing costs of the entrepreneur in this *mixed refinancing* region beyond $1 - W$. In the third region, the entrepreneur's endowment falls short of $\underline{W}(I^*)$. Consequently, credible loan repayments are too small to raise a loan with I^* in this *no financing* region.

Insert Figure 2 about here

With the help of these regions, Proposition 1 distinguishes between four general cases. Case a) corresponds to a high initial endowment of the entrepreneur, $W \geq \overline{W}\left(I^{fb}\right)$. In this case, he commands sufficient internal funds to not face a trade-off between financing costs and investment efficiency. The reason is that any combination of W and $I^* \leq I^{fb}$ belongs to the zero capital region so that the entrepreneur maximizes profits by demanding a loan that i) is completely refinanced by deposits, and ii) stipulates an allocation $I^* = I^{fb}$. This case thus refers to firms that do not have to pay an external finance premium. For them, internal and external funds are perfect substitutes: intra-marginal changes in the available amount of internal funds can be offset by opposite changes in the amount borrowed from the bank, and there is yet no change in the total cost of finance $E[H_s] + W = 1$ even without adjusting the investment plans. An additional unit of internal funds thus merely replaces one unit of deposits, for which the opportunity costs are the same, without affecting the scope for efficient investments in either of the states.

If the entrepreneur has an initial financial endowment $W \leq \overline{W}\left(I^{fb}\right)$, he will be financially constrained. He either has to pay an external finance premium when allocating resources according to the first-best, or does not get a bank loan at all. Case b) in Proposition 1 specifies the implications of an intermediate endowment $\overline{W}\left(I^{fb}\right) > W \geq \underline{W}\left(I^{fb}\right)$: According to (8), holding the allocation unchanged, an intra-marginal variation in internal funds could not be offset by an opposite variation in the borrowed amount without changing the total cost of finance. The reason is that the banker has already exhausted her potential to issue deposits to the fullest. A change in W has to be compensated by opposite changes in bank equity capital, which is a more costly form of finance. Hence, even when the entrepreneur could in principle still ensure symmetric investment by setting $I^* = I^{fb}$, he will not do so as he faces a trade-off between investment efficiency and the costs of finance. He will lower I^* to $\max\left\{\bar{I}, I^B\right\}$:

- At $\bar{I}$, the zero capital region begins so that financing costs will be minimized and equal to $1-W$. Although the banker does not extract a rent, there is an external finance premium as an increase in W would allow to earn the otherwise forsaken returns on investment due to the inefficient allocation in the bad state.

- At I^B, the marginal benefits from reducing financing costs, as specified on the right hand side of (11), equal the expected marginal costs of inefficient investments as given by the left hand side of (11). In this case, the external finance premium not only refers to a misallocation of resources but also to the rent paid to the banker in the good state. Note that investments in the good state are irrelevant for this trade-off since the entrepreneur is sufficiently wealthy to invest symmetrically in the good state irrespective of the chosen loan contract.

In case c), the entrepreneurs has a low endowment of internal funds in the range $\underline{W}\left(I^{fb}\right) > W > \underline{W}(0)$. These funds are too small to allow for a loan with $I^* = I^{fb}$. Instead, the most efficient allocation that a contract can stipulate for the bad state is $\underline{I} < I^{fb}$. When this contract is chosen, the loan has to be refinanced in part by bank capital and the allocation will be $\underline{I}$ regardless of the state. By further lowering I^* below $\underline{I}$, the entrepreneur can not only lower his financing costs as in case b). Instead, he can also use the associated additional leeway to reduce investment inefficiency in the good state. The entrepreneur does so until either the marginal efficiency gains in the good state (plus the decrease in financing costs) on the right hand side of (12) equal the associated efficiency loss in the bad state on the left hand side, or until the zero capital region is reached. However, it may be that the benefits from reducing I^* below $\underline{I}$ never outweigh the loss of investment efficiency in the bad state. Then, the entrepreneur writes $\underline{I}$ in the loan contract.

Finally, if the entrepreneur's wealth is very low with $W \leq \underline{W}(0)$, he will be too poor to obtain a loan at all.[9]

The discussion so far has shown that, ceteris paribus, a decrease in the amount of internal funds of an entrepreneur will have two implications. First, the entrepreneur will invest relatively more in the tangible asset. Second, the bank will refinance a larger share of the loan by capital. From these two implications, we can conclude that banks with a stronger capital basis will tend to grant loans to customers who have more tangible assets.

[9] In this case, the entrepreneur cannot escape credit rationing by using direct finance. With direct finance, creditors do not have a banker's ability to monitor the entrepreneur. Consequently, the entrepreneur can threaten to direct all resources to project A at t_1. Hence, issuing corporate bonds is equivalent to a bank loan with $I^* = 1$. Such a loan allows the banker to always invests efficiently but limits loan repayments to $\Psi_s(1)$ in state s. Consequently, his debt capacity is $p\Psi_g(1) + (1-p)\Psi_b(1)$, so that his financial endowment must be at least $W \geq 1 - p\Psi_g(1) - (1-p)\Psi_b(1)$, which is higher than $\overline{W}(I^{fb})$ for a reasonably large parameter space. So only those entrepreneurs who can already sign a bank loan contract that always allows first-best investments have access to direct financing.

4 Investment (in-)efficiency and minimum capital requirements

In the last section we studied the link between the firm-internal allocation of resources and a firm's financing cost. In this section we apply this framework to explore how the regulation of bank capital can achieve improvements in the allocation. We do so in two steps. First, we characterize the constrained efficient allocation of corporate resources and argue that in the presence of a financial constraint, firms have an incentive to deviate from it. Second, we argue that there is a scheme of minimum capital-to-asset ratios for which firms, no matter whether they face a financial constraint, will implement the constrained efficient allocation.

4.1 Constrained efficiency

In a first-best world, the efficient investment pattern of the entrepreneur would be to always balance marginal returns on investment in the two projects A and B irrespective of the state of nature. However, we have seen in the preceding section that a poor entrepreneur obtains a bank loan only if he commits to invest less than half of the intermediate good in project A in the bad state. For him, a bank loan with $I^* = I^{fb}$ implies renegotiation-proof repayments that are too small to let the financiers be willing to lend out funds.

Given the frictions in financial contracting that result from debt renegotiations, a social planner can only strive for a second-best (constrained efficient) solution, i. e. for maximizing expected total returns taking into account the outcome of future debt renegotiations. The corresponding optimization problem reads

$$\max_{H^*,I^*,D^*} E\left[\Pi_s\right] := E\left[R\left(I_s\right) + R\left(1 - I_s\right)\right] - 1 \tag{13}$$

$$s.t. \; (3), (4), (6) \text{ and } (7).$$

Let the solution to this optimization problem be denoted by *sb*. We obtain

Proposition 2. *The constrained (second-best) efficient solution has the following properties:*

a) If $W \geq \overline{W}\left(I^{fb}\right)$*, then*

$$\begin{aligned} I^{*}_{sb} &= I^{fb} = I^{*}_{eq}, \\ I_b &= I^{fb}, \\ I_g &= I^{fb}. \end{aligned}$$

b) If $\overline{W}\left(I^{fb}\right) > W \geq \underline{W}\left(I^{fb}\right)$*, then*

$$\begin{aligned} I^{*}_{sb} &= I^{fb} > I^{*}_{eq}, \\ I_b &= I^{fb}, \\ I_g &= I^{fb}. \end{aligned}$$

c) If $\underline{W}\left(I^{fb}\right) > W > \underline{W}(0)$*, then*

$$\begin{aligned} I^{*}_{sb} &= \min\left\{\underline{I}, \max\left\{\bar{I}, I^{D}\right\}\right\} \geq I^{*}_{eq}, \\ I_b &= \min\left\{\underline{I}, \max\left\{\bar{I}, I^{D}\right\}\right\}, \\ I_g &= \min\left\{I^{fb}, \underline{I} + \tfrac{(2-p)\left[\Psi_b\left(I^{*}_{sb}\right) - \Psi_b(\underline{I})\right]}{p(1-\mu)\beta_g}\right\}, \end{aligned}$$

where $I^{D} > I^{C}$ *is implicitly defined by*

$$(1-p)\left[R'\left(I^{D}\right) - R'\left(1-I^{D}\right)\right] = (2-p)\tfrac{\beta_b}{\beta_g}\left[R'\left(I_g\right) - R'\left(1-I_g\right)\right], \tag{14}$$

and where $I^{D} > \underline{I}$ *only if* $1-p > \frac{\beta_b}{\beta_g - \beta_b}$.

Proof. See Appendix. □

The proposition shows that the entrepreneur tends to commit to higher reinvestments in the project with higher asset tangibility than socially desirable. When concluding contracts, he tends to care not only about project returns, but also about financing costs. These costs comprise the initial outlay of 1 dollar for the physical investment at t_0 as well as the rents paid to the banker, which depend on the bank's capital structure. From a social planner's point of view, these rents are irrelevant as they reflect only a redistribution of returns from the entrepreneur to the banker.

The exception is case a), in which the entrepreneur possesses plenty of internal funds $W \geq \overline{W}\left(I^{fb}\right)$. In this case, bank capital is of no use for him. He always choose a loan with $I^* = I^{fb}$ which already allows for efficient investment in all states.

In case b) characterized by $\overline{W}\left(I^{fb}\right) > W \geq \underline{W}\left(I^{fb}\right)$, though the social optimum is also characterized by investment efficiency in all states, it will not be implemented voluntarily by the entrepreneur. Instead, he asks for a contract that commits him to invest less than I^{fb} in project A in the bad state, while retaining sufficient scope to make investments according to the first-best in the good state.

In case c) with $\underline{W}\left(I^{fb}\right) > W > \underline{W}(0)$, the entrepreneur is too poor to obtain a loan with $I^* = I^{fb}$. He then is unable to always invest efficiently. Consequently, the social planner aims to trade off project returns in the good and in the bad state. Two scenarios can be distinguished in this case. First, when the probability of default (PD) is relatively high, $1-p > \frac{\beta_b}{\beta_g-\beta_b}$, the planner would prefer to induce more efficient investments in the bad state than in the good state. However, this is impossible since I^* cannot be made state contingent. Therefore, the best a planner could do is to enforce the most efficient feasible allocation $I^*_{sb} = \underline{I} < I^d$, so that the entrepreneur chooses the same investment pattern $\underline{I}$ in each state. In this scenario, marginal returns on investments are not balanced across states. Second, when PD is relatively small with $1-p \leq \frac{\beta_b}{\beta_g-\beta_b}$, the social planer would opt for $I^*_{sb} = \max\left\{\bar{I}, I^D\right\} < \underline{I}$.

The contractual allocation I^D as defined in (14) implements a balancing of marginal returns across states. It is strictly larger than I^C because rents of the banker are not part of the social planer's optimization problem. The contractual allocation $\bar{I}$ marks the begin of the zero capital region, in which a further decrease of I^* has no consequence for the actual investment decisions of the entrepreneur.

4.2 Bank capital regulation and investment efficiency

Proposition 2 has shown that inefficiencies in financial contracting arise in the endeavor of the entrepreneur to economize on the costs of bank capital. Capital standards for banks may enhance efficiency by altering the incentive structure for bank-financed firms.

To operationalize bank capital regulation, we have to define a bank's capital-to-asset ratio as of t_0. In accordance with accounting standards, the loan is booked on the asset side of the bank's balance sheet with its face value $1-W$, while liabilities consist of deposits with face value D^* and capital with book value $1-W-D^*$. Hence, the capital-to-asset ratio k at t_0 is $k := \frac{1-W-D^*}{1-W}$.

Recall from the preceding section that in absence of regulation, the volume of deposits issued by the bank at t_0 cannot exceed $\Psi_b\left(I^*\right)$. Imposing a regulatory minimum requirement $k^{\min}$ on bank capital adds a second upper bound $D^{\max} := \left(1-k^{\min}\right)(1-W)$ on the volume of deposits.[10] In conjunction with (8), this upper bound leads to a (second) lower bound $\left(1+k^{\min}\right)(1-W)$ on the entrepreneur's effective financing costs, which brings us to

[10] Note that at t_1 capital standards no longer restrict financial contracting because the banker's monitoring skills are no longer required. She could, e. g., sell the loan at a price equal to what she would get from the entrepreneur at t_3.

Proposition 3. *There exists a scheme of minimum capital-to-asset ratios $k^{\min}$ that completely eliminates any incentive of the entrepreneur to write inefficient contracts. This scheme has the following properties*

$$k^{\min} = \begin{cases} 0 & \text{if} \quad W \geq \overline{W}\left(I^{fb}\right) \\ \frac{1-W-\Psi_b(I^{fb})}{1-W} & \text{if} \quad \overline{W}\left(I^{fb}\right) > W \geq \underline{W}\left(I^{fb}\right) \\ \frac{1-W-\Psi_b(I^{sb})}{1-W} & \text{if} \quad \underline{W}\left(I^{fb}\right) > W > \underline{W}(0) \end{cases} \tag{15}$$

Proof. Omitted. □

This proposition reflects the principle that in absence of regulation, any contractual allocation I^*, including the constrained efficient contractual allocation I^*_{sb}, is linked to a unique level of minimum financing costs. According to (8) and the upper bound $\Psi_b(I^*)$ on the volume of deposits, these minimum financing costs are equal to $2(1-W) - \Psi_b(I^*)$. They are lower, the lower is I^*. Imposing a capital-to-asset ratio $k^{\min}$ that balances the resulting (second) lower bound $(1+k^{\min})(1-W)$ on the financing costs with the minimum financing costs $2(1-W) - \Psi_b\left(I^*_{sb}\right)$ associated with I^*_{sb} will implement the constrained efficient contract. Though the entrepreneur could still put an I^* different from I^*_{sb} into the contract when $k^{\min}$ is imposed, he will not do so for two reasons. First, for all $I^* < I^*_{sb}$, the entrepreneur cannot conclude a preferred contract as characterized in proposition 1. This is because the bank's capital would then fall short of the minimum requirement. Instead, the capital requirement $k^{\min}$ must be observed for all I^* below I^*_{sb} so that the entrepreneur has no scope to secure himself financing costs below $(1+k^{\min})(1-W)$. Therefore, he would prefer such contracts only if they at least yielded higher expected returns on investment than the contract with I^*_{sb}. This is not true because I^*_{sb} already maximizes expected returns on investment. Second, for all $I^* > I^*_{sb}$, the contract is associated with a bank's capital-to-asset ratio above $k^{\min}$. Therefore, he would be in no way restricted by a requirement $k^{\min}$ when agreeing on

$I^* > I^*_{sb}$. However, stipulating such I^* is not rational because expected profits decrease when I^* goes beyond I^*_{sb}. Hence the entrepreneur finds it best to write I^*_{sb} into the contract when $k^{\min}$ is imposed.

Insert Table 1 about here

We further illustrate this result by the following example: Let $R(I) = I^{1/2}$, $\mu = 0$, $\beta_g = 1$, $\beta_b = 0.5$, $p = 0.5$. We then have $\overline{W}(I^{fb}) = \frac{60}{80}$, $\underline{W}(I^{fb}) = \frac{55}{80}$, and $\underline{W}(0) = \frac{30}{80}$. Table 1 summarizes the major implications for this example: Firms with $W \in \left[\underline{W}(I^{fb}), \overline{W}(I^{fb})\right)$ could invest efficiently but do so only if their bank faces a capital requirement. Without a regulation, they would ask for loans completely refinanced with deposits because this gives them a higher expected profit. For firms with less internal funds, the efficient allocation cannot be achieved. In this example, firms still ask for deposit-only loans and accept quite large losses in the value of their production. Accordingly, the potential efficiency gains through capital regulation (as a percentage increase in the expected value of the production due to regulation) are the largest for those firms which will just afford a loan refinanced without bank capital even though this requires a substantial deviation from the return-maximizing allocation. Firms with endowments close to $\underline{W}(0)$ already face very tight financial constraints. For them the scope to further reduce their investment in illiquid asset is very limited and they can raise a loan only if they allow the bank to raise the required funds to a large extent via equity shares anyway. Accordingly, the implied capital ratio is already large and the potential efficiency gains through imposing a further minimum capital ratio are small.

5 Discussion and further implications

In the last section we showed that there is a link between the investment behavior of bank-financed firms and bank capital regulation. In this section we discuss this finding and various further applications of our framework.

5.1 Costs of deposits and bank equity

In the above analysis the bank loan is more costly to the entrepreneur, the more it is refinanced by bank equity, although shareholders and depositors receive the same return on their investment. This feature has been due to the assumption of perfect competition among financiers, who have all equal access to the same investment alternative.

The markets for equity shares and deposits may be, however, separated. For example, a few financiers could be in better position to negotiate with a banker over the bank's earnings giving them an edge in terms of the required return for their equity investment in the bank (as for example in Holmström and Tirole, 1997). In this scenario it may not be the banker who extracts a rent but the bank's shareholders. Incorporating this scenario into our model would not change its qualitative results: Still, the bank loan would be cheaper the more it was refinanced by deposits, and the cost differential between deposits and equity capital would be due to some inefficiency associated with rent extraction. If both frictions came into play at the same time, the cost differential would increase. Without a regulation of bank capital, the entrepreneur would then have even stronger incentives to save on the even higher cost of capital by directing more resources to the project with higher liquidation proceeds. Also, a tightening of the capital requirement would have a stronger impact on the entrepreneur's incentives.

Another reason for why deposits are cheaper for the entrepreneur than bank equity arises in the presence of an unfairly priced deposit insurance. The analysis so far has not considered deposit insurance, but taking it explicitly into account would not be crucial for the major results. As long depositors enjoy only limited coverage, which applies to many countries, some depositors such as large ones, institutional investors, corporate enterprises or other banks, will be excluded from insurance. The major incentive mechanism for the banker will be still at work (Diamond and Rajan, 2001). More importantly, an unfairly priced deposit insurance implies that insured deposits are a subsidized financial instrument for banks. Firms who demand their most preferred loans from banks will not account for any social cost of the subsidy and thus ask for loans that are again overly refinanced by deposits. As it is such a wedge between the cost of bank equity and deposits that incites firms to write inefficient loan contracts with banks, our main results will be qualitatively unchanged in the presence of deposit insurance.

5.2 Firms' access to finance

Worries are often articulated that the regulation of bank capital impairs the cost and availability of funds. This is expected to hurt especially firms that are financially constrained. With those firms being squeezed out of the market first, an economy-wide efficient allocation of financial resources could be hampered as a result of tighter regulation.[11] We next address this concern in the context of our model.

In our model, some variables that are important for the efficiency of financial contracts are not verifiable. This deficiency results not only in a borrowing constraint as the major financial friction, it also implies that a regulator lacks the information that is required to implement the constrained-efficient allocation by imposing minimum capital ratios. Hence, the regulator may chose a single capital ratio that applies to all loans. Consider again the above example (Table 1) and suppose that the regulator would introduce a regulatory capital ratio of about 17%, applicable to all loans. Those firms, for which the efficiency gains would be the greatest, are then provided with the proper incentives. Weaker firms with very few internal funds would not suffer from the regulation. For them, the capital ratio implied by the contract that they would prefer in the absence of the reulation is even larger. In addition, the potential efficiency gains are not that large to make it worthwhile for the regulator to target at this group by imposing even tighter standards. For the remaining firms a capital ratio of 17% would be binding but affordable as they are financially strong enough. Hence,

[11] For a critical discussion of this view see Admati et al. (2010).

asking for 17% capital ratio may look like a sensible compromise. However, when the imposed capital requirement would be only slightly higher (above 20% in the example), the firms with the lowest financial endowment W would actually lose their access to finance completely, while other firms will not implement the constrained efficient allocation. A regulator thus faces an additional trade-off that has not earned attention in the discussion of optimal capital regulation so far: For some firms a high capital ratio may be needed to achieve a constrained efficient allocation of resources across their projects. Achieving this type of allocative efficiency within firms, however, conflicts with achieving allocative efficiency across firms when others lose their access to finance due to regulation.

These considerations lead to the question under what conditions the establishment of minimum capital requirements for banks are likely to be socially beneficial from a theoretical point of view. Although the normative implications of the model are rather limited, a few conclusions in this respect can be drawn by taking a cross-country perspective. First, imposing minimum capital-to-asset ratios for banks are likely to be socially beneficial in countries with a large share of firms with an intermediate financial endowment. In this case, firms with very large or very small financial endowments are rather rare and the allocative efficiency across firms is not very much affected by the capital regulation. Second, in countries where intangible capital such as human capital, R&D, brands, and IT, is an important factor in production, the demand for tangible and liquid assets should be particularly strong. As this differential in the value of tangible versus intangible assets creates the incentive for firms to make inefficient use of their financial resources, the beneficial effects of a regulation of bank capital on allocative efficiency should be stronger in those countries. Finally, in countries with well developed legal systems and financial markets, the value added by banks through monitoring borrowers is rather small. Firms can commit to a specific allocation of resources by writing (almost) complete contracts and can trade the risks of asset price changes on (more) complete financial markets. The ability of banks to extract rents is thus limited and so is the effect of banks' capital structure on firms' financing costs. Therefore, the additional benefits of improving allocative efficiency within firms through bank capital regulation should be small.

5.3 Financial stability

Our focus has been the link between bank capital regulation and the investment behavior of bank-financed firms. So far, we restricted attention to a banker who is completely unwilling to jeopardize her existence. According to (6), this unwillingness resulted in the condition $D^* \leq H_b$. This restriction on deposits ensured that the banker was able to fully service depositors in all states so that the bank survived in any circumstance. In theory, at least, the entrepreneur could also ask for a bank loan that induces the banker to implement a fragile capital structure with $D^* > H_b$. This has several interesting additional implications. First, there is no longer any need to refinance the loan with capital. By concluding a loan contract that is associated with $D^* = H_g$, the entrepreneur can force the banker to use deposits as the sole means of refinancing. As a consequence, the entrepreneur can avoid rent extraction by the banker. Second, the bank will fail when the bad state occurs at t_1. As depositors anticipate that the prospective loan repayment H_b of the entrepreneur to the bank would fall short of their claim in this state, they will run on the bank immediately and take possession of the claim on the entrepreneur. Hence, they have to renegotiate directly with the entrepreneur at t_1 and t_2. In renegotiations with depositors at t_1, the entrepreneur will threaten to direct all resources towards the illiquid project. Depositors can do nothing about this as they are lacking the expertise and technology to monitor the allocation of funds. Although the entrepreneur is thus free to implement the efficient allocation in the bad state, depositors can collect at most $\Psi_b(1)$ from the entrepreneur. Third, the banker will extract no rent in the good state so that depositors will get at most $\Psi_g(I^*)$ in this state. All in all, also under a fragile bank capital structure, an entrepreneur will face a borrowing constraint unless he possesses plenty internal funds. This borrowing constraint stems from participation constraint of depositors which requires $1-W \leq p\Psi_g(I^*)+(1-p)\Psi_b(1)$. With a fragile bank, the regulation of bank capital not only improves the allocation of resources but also achieves bank stability; the minimum capital-to-asset ratio that eliminates the adverse incentives on the firms' level is the same as described in proposition 3.

Capital regulation can also affect financial stability through the link we have established between bank capital structure and corporate investment. Over the last decades, intangible capital such as research and development, human capital, and information technology, has gained in importance in the production process. The drawback of intangible capital is that it is not easy to finance. Therefore, firms need easily re-deployable, or liquid, assets to cross-pledge them as collateral when seeking external finance for those activities. Giglio and Severo (2012) have developed a model of economic growth that explains how the increased demand for tangible assets as means of collateral (used in borrowing for accumulating intangible assets) leads to asset price bubbles which threaten the stability of the financial system and the economy as a whole. In their model, banks do not play any specific role. The argument developed in our paper, however, fits well into their reasoning: Bank-financed firms may have an incentive to demand too many tangible assets in an attempt to lower their financing cost. This incentive can additionally fuel a price bubble on the market for liquid assets. In this context, a regulation of bank capital can reduce momentum in the asset markets by lowering the demand for liquid assets on the firm level.

A similar point can be made about one of the causes of the world financial crisis. Prior to the crisis, households in the US, but also in Spain and Ireland, were considered to experience a shift towards a new, steeper path of economic growth (caused for example by technological progress and deeper integration of the world economy). In this situation, intertemporally optimizing households wanted to capitalize on some of the resulting future income gains. Pledging future income on credit markets, however, is associated with rather high financing costs. Hence, in order to economize on their financing costs, households preferred to pledge other, more liquid and tangible assets, especially their homes. As a result, households used their tangible assets as an ATM to finance their increased consumption expenditures, accompanied by increases in mortgages and a surge in house prices (Zhu et al., 2012). A tighter regulation of bank capital might have been able to limit these adverse developments by taking agents the incentive to overly rely on liquid assets in obtaining finance.

5.4 Empirical implications

Our model makes several testable predictions that may guide future empirical research. In this section, we will discuss them in two steps. We start with the predictions of Proposition 1. Then, we turn to Proposition 3.

The first implication of Proposition 1 relates to the empirical analysis of bank loan contracts and how they are amended when credit market conditions change: the proposition suggests that bank financed firms change their investment plans in favor of intangible assets when assets appreciate in value, but stick to their original plans when assets depreciate.

The second empirical implication refers to the relation between banks' funding structure and their customers' asset structure: Proposition 1 predicts that banks with a larger capital basis lend to customers with fewer tangible assets. A further implication is that bank-financed firms tend to deviate from the principle of balancing marginal returns on investment across projects and to *excessively* favor investments associated with the most tangible assets. Of course, bank-financed firms will have to put more weight on those assets as it is this which serves to convince financiers to place their funds into the firm in the first place. This characteristic is not unique to our model (see Marquez and Yavuz, 2013). However, in the absence of an optimum capital regulation regime, a firm may have incentive to deviate even further from balancing the marginal returns than needed to secure access to external finance.

One potential avenue to validate this prediction could be to test whether the expected collateral value of tangible assets (or, in generalized terms, expected pledgeable income) exceeds the face value of debt for bank-financed firms and whether this excess collateral has an influence on the firms' costs of borrowing. For example, consider a firm, which has been able to raise a loan from a bank with a zero capital basis, that refinances loans with deposits only. The firm will repay its debt in any event since pledgeable income covers the face value of debt even in bad times. However, this also means that the *expected* value of tangible assets is higher than the face value of debt. In contrast, when a reallocation of resources towards balanced marginal products would be associated not only with higher financing cost but with a loss of bank finance, our hypothesis was rejected. By the same argument, extending the model to variable investment scales would imply that a bank-financed firm does not fully exploit its debt capacity but tends to underinvest in an undue manner. This qualification means that although the firm is in principle capable to borrow more for investing into projects associated with intangible assets, it refrains from doing so.

The model also makes testable predictions about the effect of bank capital requirements on the tangibility of bank customers' assets. Proposition 3 and its discussion suggests that the level of minimum capital requirements for banks is negatively related to the degree of asset tangibility. The higher is the capital requirement, the smaller will be the incentive of firms to economize on financing costs by investing in highly tangible assets. This implication could be put to an empirical test by means of a natural experiment: during the recent financial crisis, regulators in some countries have opted for discretionary increases in the capital requirements for a few selected banks. This could serve as a treatment and control experiment to elicit the response of firm behavior to changing regulatory norms applied to their respective banks.[12]

[12] Of course, one must bear in mind that regulators have not selected banks in the treatment group randomly.

To conclude, the model has also implications for corporate valuation in that inefficient firm-internal cross-subsidization may not only result from inefficiencies within the firm. Instead, a firm's tendency to direct more resources towards one project than indicated by its respective value of investment, such as Tobin's Q, can also be due to the firm's aim to capitalize on the project's asset tangibility in order to reduce financing costs. This perspective also suggests to include the regulation of banks as an independent and hitherto disregarded determinant of a corporation's value.

6 Summary

In this paper we have investigated the effects of bank capital regulation on the allocation of resources within multi-project firms. The basic insight is that conglomerates face a trade-off between allocative efficiency and financing costs. We have argued that the more a bank is refinanced by deposits, the lower are the firm's financing costs because it then saves on costly bank capital. At the same time, more deposits require the firm to commit itself to allocating resources mainly to projects where tangibility (but not productivity) of assets is highest. This is because more deposits can be issued only when repayments to the banker in the case of default will be sufficiently large.

Given this trade-off, firms are inclined to write loan contracts that deter them from allocating resources efficiently as they can save on financing costs in doing so. As the latter are, however, solely a matter of redistribution, a social planner prefers to force firms to choose loan contracts associated with less inefficient investments. We have shown that imposing a properly designed minimum capital-to-asset ratio for firms' lending banks can help to achieve this goal. The argument is that with minimum capital requirements the regulator effectively puts a lower bound on firms' financing costs, thereby restricting the set of feasible contracts to those that prevent firms from investing overly inefficiently.

Appendix

Proof of Lemma 2

It follows from (2) and the definition of $\Psi_s(I)$ that the entrepreneur can only make offers with $\tilde{H}_1 \geq \min\{H^*, \Psi_s(I^*)\} =: \tilde{H}_1^{\min}$ and $\tilde{I}_1 \leq I^* + \max\left\{\frac{\Psi_s(I^*)-H^*}{(1-\mu)\beta_s}, 0\right\} =: \tilde{I}_1^{\max}$. Since $\frac{\partial \pi_s^e}{\partial \tilde{H}_1} \leq 0$ for all $\tilde{I}_1 \leq \tilde{I}_1^{\max}$, he will offer $\tilde{H}_1 = \tilde{H}_1^{\min}$, see (3). Insertion of this in π_s^e yields $\pi_s^e = R(\tilde{I}_1) + R(1-\tilde{I}_1) - \tilde{H}_1^{\min} - W$ for all $\tilde{I}_1 \leq \tilde{I}_1^{\max}$. Since $\frac{\partial \pi_s^e}{\partial \tilde{I}_1} = 0$ only if $\tilde{I}_1 = I^{fb}$ and $\frac{\partial^2 \pi_s^e}{\partial \tilde{I}_1^2} < 0$, the entrepreneur will offer and implement $\tilde{I}_1 = \min\left\{I^{fb}, \tilde{I}_1^{\max}\right\}$, see (4).

Proof of Proposition 1 and 2

We prove the propositions in three steps. First, we derive H_x^* with $x = eq, sb$ for a given D^* and I^*. Then, we derive D_x^* for a given I^*. As a last step, we derive I_x^*.

Repayment obligation We know from (3) and (4) that $\frac{\partial H_s}{\partial H^*} \geq 0$, $I_s \leq I^{fb}$ and $\frac{\partial I_s}{\partial H^*} \leq 0$, so that (5), (13) and $\mathscr{R}(I_s) := R(I_s) + R(1-I_s)$ imply

$$\frac{\partial E[\pi_s^e]}{\partial H^*} = p\underbrace{\mathscr{R}'(I_g)}_{\geq 0}\underbrace{\frac{\partial I_g}{\partial H^*}}_{\leq 0} + (1-p)\underbrace{\mathscr{R}'(I_b)}_{\geq 0}\underbrace{\frac{\partial I_b}{\partial H^*}}_{\leq 0} - \underbrace{\frac{\partial E[H_s]}{\partial H^*}}_{\geq 0} \leq 0,$$

$$\frac{\partial E[\Pi_s]}{\partial H^*} = p\underbrace{\mathscr{R}'(I_g)}_{\geq 0}\underbrace{\frac{\partial I_g}{\partial H^*}}_{\leq 0} + (1-p)\underbrace{\mathscr{R}'(I_b)}_{\geq 0}\underbrace{\frac{\partial I_b}{\partial H^*}}_{\leq 0} \leq 0.$$

Accordingly, for a given I^* and D^*, H_x^* with $x = eq, sb$ corresponds to the smallest H^* for which (7) is met. After insertion of (3) in (7) and rearranging terms, we can conclude

$$p\min\left\{H_x^*, \Psi_g(I^*)\right\} + (1-p)\min\left\{H_x^*, \Psi_b(I^*)\right\} = 2(1-W) - D^*. \tag{16}$$

Volume of deposits We can infer from (5), (13) and (16) that

$$\frac{\partial E[\pi_s^e]}{\partial D^*} = \underbrace{\frac{\partial E[\pi_s^e]}{\partial H_{eq}^*}}_{\leq 0} \underbrace{\frac{\partial H_{eq}^*}{\partial D^*}}_{\leq 0} \geq 0, \quad \frac{\partial E[\Pi_s]}{\partial D^*} = \underbrace{\frac{\partial E[\Pi_s]}{\partial H_{sb}^*}}_{\leq 0} \underbrace{\frac{\partial H_{sb}^*}{\partial D^*}}_{\leq 0} \geq 0.$$

Accordingly, for a given I^*, D_x^* with $x = eq, sb$ corresponds to the largest D^* for which (6) is met. After insertion of (3) in (6) and rearranging terms, we can conclude

$$D_x^* = \min\{H_x^*, \Psi_b(I^*)\}. \tag{17}$$

Allocation We can infer from (5) and (13) that

$$\frac{\partial E[\pi_s^e]}{\partial I^*} = p\mathscr{R}'(I_g)\frac{\partial I_g}{\partial I^*} + (1-p)\mathscr{R}'(I_b)\frac{\partial I_b}{\partial I^*} - \frac{\partial E[H_s]}{\partial I^*}, \tag{18}$$

$$\frac{\partial E[\Pi_s]}{\partial I^*} = p\mathscr{R}'(I_g)\frac{\partial I_g}{\partial I^*} + (1-p)\mathscr{R}'(I_b)\frac{\partial I_b}{\partial I^*}. \tag{19}$$

Moreover, solving (16) and (17) for H_x^* and D_x^* and insertion of the results in (3) and (4) yields

- for $W =: \overline{W}(\bar{I}) \geq \overline{W}(I^*)$ and thus $I^* \leq \bar{I}$

$$I_b = \min\left\{I^{fb}, \bar{I}\right\} \qquad D_x^* = 1 - W, \tag{20}$$

$$I_g = \min\left\{I^{fb}, \underline{I} + \frac{(2-p)\left[\Psi_g(\underline{I}) - \Psi_b(\underline{I})\right]}{2(1-\mu)\beta_g}\right\}, \qquad H_x^* = 1 - W, \tag{21}$$

$$E[H_s] = 1 - W, \tag{22}$$

- for $\overline{W}(I^*) > \overline{W}(\bar{I}) := W =: \underline{W}(\underline{I}) \geq \underline{W}(I^*)$ and thus $I^* \in (\bar{I}, \underline{I}]$

$$I_b = \min\left\{I^{fb}, I^*\right\}, \qquad D_x^* = \Psi_b(I^*), \tag{23}$$

$$I_g = \min\left\{I^{fb}, \underline{I} + \tfrac{(2-p)[\Psi_b(I^*)-\Psi_b(\underline{I})]}{p(1-\mu)\beta_g}\right\}, \qquad H_x^* = 1 - W + \tfrac{2-p}{p}\left(1-\Psi_b(I^*) - W\right), \tag{24}$$

$$E[H_s] = 1 - W + \left(1 - \Psi_b(I^*) - W\right). \tag{25}$$

- for $\underline{W}(I^*) > \underline{W}(\underline{I}) := W$ and thus $I^* > \underline{I}$, (16) and (17) cannot be solved so that a contract with $I^* > \underline{I}$ is unavailable.

In conjunction with (18), (19), $\mathscr{R}'\left(I^{fb}\right) = 0$ and $\frac{\partial \Psi_b(I^*)}{\partial I^*} = -(1-\mu)\beta_b$, this implies

$$\frac{\partial E[\pi_s^e]}{\partial I^*} = \begin{cases} 0 & \text{if} \quad I^* \leq \bar{I}, \\ (1-p)\mathscr{R}'\left(\min\left\{I^{fb}, I^*\right\}\right) - \mathscr{R}'(I_g)(2-p)\frac{\beta_b}{\beta_g} - (1-\mu)\beta_b & \text{if} \quad I^* \in (\bar{I}, \underline{I}], \end{cases} \tag{26}$$

$$\frac{\partial E[\pi]}{\partial I^*} = \begin{cases} 0 & \text{if} \quad I^* \leq \bar{I}, \\ (1-p)\mathscr{R}'\left(\min\left\{I^{fb}, I^*\right\}\right) - \mathscr{R}'(I_g)(2-p)\frac{\beta_b}{\beta_g} & \text{if} \quad I^* \in (\bar{I}, \underline{I}], \end{cases} \tag{27}$$

where I_g is defined by (24). This brings us to four cases.

a) Let $W \geq \overline{W}\left(I^{fb}\right)$ and thus $\underline{I} > \bar{I} \geq I^{fb}$. Then, (20) and (23) imply $I_b = I^{fb}$ while (21) and (24) imply $I_g = I^{fb}$. Insertion of this in (26) and (27) yields

$$\frac{\partial E[\pi_s^e]}{\partial I^*} = \begin{cases} 0 & \text{if} \quad I^* \leq \bar{I}, \\ -(1-\mu)\beta_b & \text{if} \quad I^* \in (\bar{I}, \underline{I}], \end{cases}$$

$$\frac{\partial E[\pi]}{\partial I^*} = \begin{cases} 0 & \text{if} \quad I^* \leq \underline{I}. \end{cases}$$

We can conclude that $I_{eq}^* = I^{fb} \leq \bar{I}$ and $I_{sb}^* = I^{fb}$.

b) Let $\overline{W}\left(I^{fb}\right) > W \geq \underline{W}\left(I^{fb}\right)$ and thus $\underline{I} \geq I^{fb} > \bar{I}$. Then, (20) and (23) imply $I_b = \max\left\{\bar{I}, \min\left\{I^{fb}, I^*\right\}\right\}$ while (21) and (24) imply $I_g = I^{fb}$. Insertion of this in (26) and (27) yields

$$\frac{\partial E[\pi_s^e]}{\partial I^*} = \begin{cases} 0 & \text{if} \quad I^* \leq \bar{I}, \\ (1-p)\mathscr{R}'(I^*) - (1-\mu)\beta_b & \text{if} \quad I^* \in \left(\bar{I}, I^{fb}\right], \\ -(1-\mu)\beta_b & \text{if} \quad I^* \in \left(I^{fb}, \underline{I}\right], \end{cases}$$

$$\frac{\partial E[\pi]}{\partial I^*} = \begin{cases} 0 & \text{if} \quad I^* \leq \bar{I}, \\ (1-p)\mathscr{R}'(I^*) & \text{if} \quad I^* \in \left(\bar{I}, I^{fb}\right], \\ 0 & \text{if} \quad I^* \in \left(I^{fb}, \underline{I}\right]. \end{cases}$$

We can conclude that $I_{eq}^* = \max\left\{\bar{I}, I^B\right\} \in \left[\bar{I}, I^{fb}\right)$ and $I_{sb}^* = I^{fb}$.

c) Let $\underline{W}\left(I^{fb}\right) > W \geq \underline{W}(0)$ and thus $I^{fb} > \underline{I} \geq 0$. Then, (20) and (23) imply $I_b = \max\left\{\bar{I}, I^*\right\}$. Insertion of this in (26) and (27) yields

$$\frac{\partial E[\pi_s^e]}{\partial I^*} = \begin{cases} 0 & \text{if} \quad I^* \leq \bar{I}, \\ (1-p)\mathscr{R}'(I^*) - \mathscr{R}'(I_g)(2-p)\frac{\beta_b}{\beta_g} - (1-\mu)\beta_b & \text{if} \quad I^* \in \left(\bar{I}, \underline{I}\right], \end{cases}$$

$$\frac{\partial E[\pi]}{\partial I^*} = \begin{cases} 0 & \text{if} \quad I^* \leq \bar{I}, \\ (1-p)\mathscr{R}'(I^*) - \mathscr{R}'(I_g)(2-p)\frac{\beta_b}{\beta_g} & \text{if} \quad I^* \in \left(\bar{I}, \underline{I}\right], \end{cases}$$

where I_g is defined by (24). We can conclude that $I_{eq}^* = \min\left\{\underline{I}, \max\left\{\bar{I}, I^C\right\}\right\} \in \left[\bar{I}, \underline{I}\right]$ and $I_{sb}^* = \min\left\{\underline{I}, \max\left\{\bar{I}, I^D\right\}\right\}$.

d) Let $\underline{W}(0) > W$ and thus $0 > \underline{I}$. Then, there is no contract available.

The remaining entries in Proposition 1 can be obtained by inserting I_{eq}^* in equations (20) to (25), respectively.

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Tables and figures

Internal funds W	I^*_{eq}	Capital ratio k	Expected profit $E[\pi_s]$	I^*_{sb}	Capital ratio $k_{\min}$	Expected profit $E[\pi_s]$	Potential efficiency gain[a] (in %)
	Without regulation			**With regulation**			
$\frac{31}{80}$	0.01	19.2	0.015	0.01	19.5	0.014	0.08
$\frac{44}{80}$	0.11	0.8	0.340	0.25	17.0	0.302	2.66
$\frac{45}{80}$	0.13	0.0	0.352	0.27	17.1	0.311	2.00
$\frac{54}{80}$	0.35	0.0	0.406	0.48	19.5	0.350	0.56
$\frac{55}{80}$ $(=\underline{W}(I^{fb}))$	0.38	0.0	0.409	0.50	20.0	0.352	0.40
$\frac{59}{80}$	0.48	0.0	0.414	0.50	4.8	0.402	0.02
$\frac{60}{80}$ $(=\overline{W}(I^{fb}))$	0.50	0.0	0.414	0.50	0.0	0.414	0.00
1.00	0.50	0.0	0.414	0.50	0.0	0.414	0.00

Table 1: Example for efficiency gains through bank capital regulation.
$R(I) = I^{1/2}$, $\mu = 0$, $\beta_g = 1$, $\beta_b = 0.5$, $p = 0.5$.
[a] The potential efficiency gain is calculated as the percentage increase in the expected value of production due to regulation.

Figure 1: Sequence of events

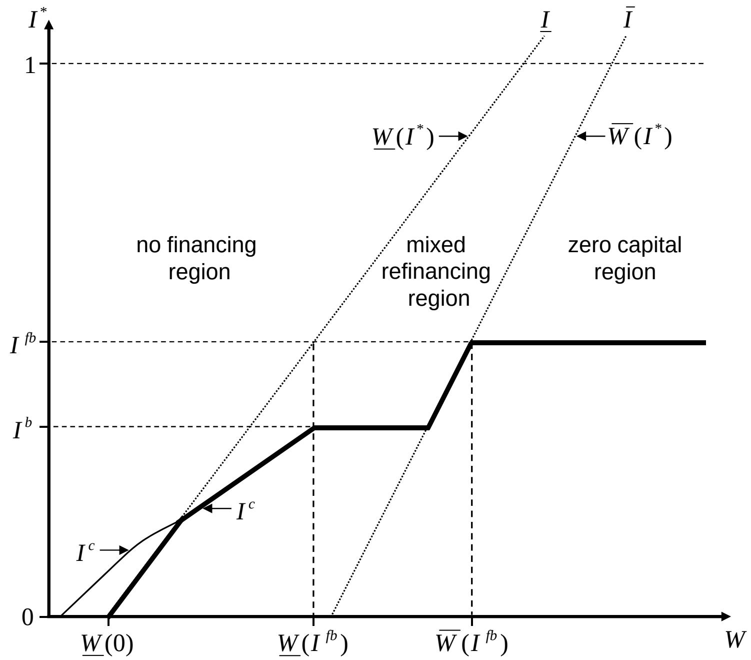

Figure 2: Contracts in a sub-game perfect equilibrium (bold line)