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Christian Keuschnigg and Michael Kogler

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School of Economics and Political Science,
Department of Economics

University of St.Gallen

Editor: Vanessa Pischulti
University of St.Gallen
School of Economics and Political Science
Department of Economics
Müller-Friedberg-Strasse 6/8
CH-9000 St.Gallen
Phone +41 71 224 23 07
Email seps@unisg.ch
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Department of Economics
University of St.Gallen
Müller-Friedberg-Strasse 6/8
CH-9000 St.Gallen
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Christian Keuschnigg, Michael Kogler

Author's address:

Prof. Christian Keuschnigg
Institute of Economics (FGN)
University of St.Gallen
Varnbüelstrasse 19
CH-9000 St.Gallen
Phone +41 71 224 30 85
christian.keuschnigg@unisg.ch

Michael Kogler, Ph.D.
Institute of Economics (FGN)
University of St.Gallen
Varnbüelstrasse 19
CH-9000 St.Gallen
Phone +41 71 224 27 53
michael.kogler@unisg.ch

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Abstract

Capital reallocation across firms is a key source of productivity gains. This paper studies the `Schumpeterian role' of banks: They liquidate loans to firms with poor prospects and reallocate the proceeds to more successful, expanding firms. To absorb liquidation losses without violating regulatory requirements, banks need to raise costly equity buffers ex ante. To economize on these buffers, they tend to real-locate too little credit and continue lending to weak firms. Tight capital standards, differentiated risk weights and low costs of bank equity facilitate reallocation. If agency costs of outside equity financing are not too high, their ability to reallocate credit renders banks more efficient than direct finance.

Keywords

Banking, credit reallocation, bank regulation, finance and growth

JEL Classification

D92, G21, G28, G33

1 Introduction

One of the main functions of financial intermediation is to efficiently allocate capital by channeling funds towards those firms that can use them most productively. Banks and other intermediaries perform functions such as credit risk analysis, monitoring of borrowers, and liquidation of loans with poor prospects. Liquidation may lead to the closure of firms without viable business models. At the same time, banks are able to recover capital which would otherwise be blocked, and to reallocate the proceeds to new ventures and expanding firms. This role of finance connects to Schumpeter's idea of 'creative destruction' and fosters innovation and growth. Only strong and well capitalized banks can adequately fulfill this function. As emphasized by Mario Draghi:[1] 'Frontloading banking sector repairs ... should in turn facilitate the Schumpeterian process of creative destruction in the economy at large – and not only by helping credit flow to younger firms, but also by facilitating debt resolution for older ones.'

The present paper investigates how banks affect creative destruction by reallocating credit from weak to strong firms. Our analysis aims at (i) identifying distortions that hamper the Schumpeterian role of banks; (ii) characterizing policy interventions and institutional changes that facilitate reallocation and reduce frictions; and (iii) evaluating productivity and welfare gains from financial intermediation. It emphasizes the interaction of credit reallocation with the capital structure of banks, which represents a key constraint on reallocation.

We set out a model of credit reallocation in which banks lend to risky firms. Firms are ex ante identical. They start with the same distribution of success probabilities which are observed at a later stage, making firms heterogeneous ex post. After the bank learns a firm's true type, it may prematurely liquidate the loan, continue lending, or, if prospects are especially good, grant additional credit for expansion investment. Loan liquidation releases funds that finance new expansion loans to the most promising firms. The model exhibits two key features: First, banks are subject to regulatory capital requirements. As

[1] Speech at the presentation ceremony of the Schumpeter Award, Vienna, March 13, 2014.

a result, credit reallocation is constrained by their (endogenous) capital structure. When prematurely liquidating loans to weak firms, banks realize losses that immediately impair equity. They can only reallocate credit as long as they have raised a sufficiently large equity buffer in advance such that they still satisfy regulatory standards after incurring losses. Second, equity is more expensive than deposits due to a standard agency problem between outside equity investors and the banker. When initially choosing their capital structure, banks thus face a trade-off. Larger equity buffers relax subsequent constraints on reallocation but entail additional agency costs.

The paper characterizes the competitive equilibrium and identifies distortions relative to a first best without an agency problem. A comparative static analysis informs about the effects of policy interventions and institutional changes. We specifically consider the design of capital regulation as well as institutional reforms that alleviate the agency problem and curb losses from loan liquidation. By influencing the capital structure of banks, these instruments relax the constraint on reallocation, strengthen their Schumpeterian role, and offer aggregate productivity gains. Eventually, a comparison to direct finance by uninformed lenders who cannot reallocate credit, highlights productivity and welfare gains from financial intermediation.

Our analysis yields five main results: First, financial intermediation boosts aggregate capital productivity because credit reallocation shifts investment to more productive firms. Second, banks reallocate too little credit. To absorb liquidation losses without violating capital standards, they must raise an equity buffer ex ante. Since agency costs render equity expensive compared to deposit funding, banks face an incentive to economize on costly equity by reducing liquidation and reallocation below its first-best level. Instead of liquidating bad loans and financing expansion of stronger firms, they continue lending to too many weak firms. Third, policymakers can design capital regulation in a way that mitigates this distortion, for example, by setting high capital requirements for old loans and low requirements for new expansion loans. To achieve this goal, regulators might differentiate risk weights to more closely reflect the default probability of borrowers. Since only the most successful firms receive expansion financing, credit risk is lower and indeed merits a lower risk weight.

Fourth, institutional reform that reduces agency costs by strengthening protection of outside equity investors against insiders is another way to stimulate reallocation. Improving access to equity at a lower cost allows banks to raise larger capital buffers, which makes them more frequently liquidate poor loans and reallocate credit to more successful firms. More efficient bankruptcy procedures could similarly boost reallocation by reducing losses from premature loan liquidation. Such interventions strengthen the Schumpeterian role of banks, foster reallocation, and promise productivity gains. Fifth, we show that the ability to perform productivity-enhancing credit reallocation renders banks more efficient than direct finance and thereby identify a novel source of welfare gains from financial intermediation. For these gains to exist, agency problems in using bank equity and liquidation costs must not be excessive.

The paper connects to the literature on finance and misallocation. Influential studies (e.g., Hsieh and Klenow, 2009; Bartelsman et al., 2013) emphasize sizable misallocation of productive factors which impairs productivity. The findings of Hsieh and Klenow (2009), for example, suggest significant TFP gains of 30-50% in China and 40-50% in India if those countries could better reallocate capital and labor and thereby reduce misallocation to the relatively efficient U.S. level. Misallocation, typically reflected in differences of marginal factor productivity across firms and plants within the same narrowly defined industry, points to frictions which prevent the reallocation of resources to better uses.

The financial sector plays two roles in this context: On the one hand, a well-functioning financial sector relaxes constraints and mitigates frictions. In an early paper, Stiglitz and Weiss (1988) anticipate the relevance of banks with specific screening and monitoring capacities for aggregate capital allocation. Wurgler (2000) provides empirical evidence demonstrating that financial development facilitates reallocation. Specifically, countries with developed financial markets are more effective in financing investment in growing industries and withdrawing funds from declining sectors. If value added in an industry increases by one percent, investment rises by only 0.22% in a country with a weakly (Indonesia) and by 0.99% in a country with a highly developed financial sector (Germany), for example. More recent studies that exploit policy changes in the United States (Acharya, Imbs, and Surgess, 2011; Bai, Carvalho and Philips, 2017) and in France (Bertrand, Schoar and Thesmar, 2007) reach similar conclusions.

On the other hand, the financial sector itself may become a source of misallocation. The literature points to weakly capitalized banks as one potential barrier to reallocation. Such banks are reluctant to restructure non-performing loans to avoid write-offs. Instead, they continue lending to distressed borrowers and engage in forbearance or 'Zombie lending'. A prominent example is the 'lost decade' in Japan during the 1990s after a massive decline in asset prices and collateral values. Troubled banks with a capital ratio close to the regulatory minimum were more likely to prolong credit to distressed borrowers (Peek and Rosengren, 2005). Such behavior led to congested product markets and slowed down the expansion of productive firms (Caballero, Hoshi and Kashyap, 2008).

After the financial crisis, similar patterns have been observed in parts of the Euro area. Acharya et al. (2019) estimate that banks which regained some lending capacity due to the ECB's Outright Monetary Transactions program but remained weakly capitalized continued lending to distressed borrowers. The share of 'Zombie' loans increased from 12-13% to 18% of total loans. Better capitalized banks, in contrast, reduced 'Zombie lending'. Schivardi, Sette and Tabellini (2017) use Italian data and estimate that credit growth to 'Zombie' firms is 25% stronger if the bank's capital ratio is below the median. Importantly, such banks hesitate to classify these loans as 'substandard' or 'bad', which would impair equity and force them to set aside loss provisions. This finding is consistent with evidence of Huizinga and Laeven (2012) that weak banks exploited their discretion to boost book values and avoid write-offs during the U.S. mortgage crisis.

Our theoretical model can rationalize several of these phenomena. It demonstrates how banks, which play a major role in financing investment particularly in Europe, facilitate the process of capital reallocation from weak to strong firms and thereby help reap aggregate productivity gains. Importantly, the paper highlights the interaction of credit reallocation with the capital structure of banks in an environment in which equity financing is subject to informational frictions and more expensive than deposit funding. It thereby provides a bank-specific explanation for misallocation and is informative about policy interventions that strengthen the Schumpeterian role of banks.

In the theoretical banking literature, models of loan liquidation and forbearance typically emphasize incentive problems at the bank level as a source of 'Zombie lending' and misallocation. Aghion, Bolton and Fries (1999) argue that bailout policies induce bank managers to hide or exaggerate loan losses, which are private information. They suggest an optimal design that preserves the manager's incentive to lend prudently and disclose truthfully the share of non-performing loans. Other papers interpret the continuation of loans to quasi-insolvent borrowers as a form of risk shifting or gambling for resurrection. Examples are Bruche and Llobet (2013), who suggest a voluntary scheme to prevent 'Zombie' lending when loan quality is only observed by banks, and Homar and van Wijnbergen (2017), who study how recapitalizing banks with an unexpectedly large number of non-performing loans can prevent forbearance.

The present paper differs from this literature in four important ways: First, we explicitly analyze the process of credit reallocation as opposed to forbearance. This distinction is important because we also picture the consequences specifically for firms (e.g., in terms of expansion, output or business creation). Second, the role of the agency problem is different. It does not directly cause insufficient reallocation of credit like, for example, risk shifting in Homar and Van Wijnbergen (2017). Instead, an agency problem is the reason why equity requires a premium, which, in turn, prevents banks from raising sufficient capital buffers in advance. The interaction of subsequent liquidation losses and regulatory restrictions constrains reallocation. Third, our analysis of economy-wide equilibrium captures the effects of bank behavior on the real economy, for instance, on firm-level and aggregate productivity. Fourth, while the existing literature analyzes a simple, unweighted capital ratio, we show how capital regulation based on risk weights allows differentiating minimum capital requirements for old and new loans. Linking capital standards more closely to actual default risk helps strengthen the 'Schumpeterian role' of banks.

Moreover, several contributions in corporate finance study capital reallocation both across or within firms. Unlike our paper, they abstract from banks altogether and model frictions at the firm level or in capital markets like credit constraints (Almeida and Wolfenzon, 2005) or capital illiquidity (Eisfeldt and Rampini, 2006). Stein (1997) demonstrates how reallocation across different projects within large firms contributes to a more efficient resource allocation. Giroud and Mueller (2015) find empirical support for such 'winner picking'. We instead consider reallocation by banks across otherwise unrelated firms.

Eventually, the paper relates to the literature on how capital requirements affect bank lending. Our result that higher capital requirements may increase credit to expanding firms echoes other recent findings, which run counter to conventional wisdom. The underlying mechanism differs, however. Instead of general equilibrium effects (Begenau, 2019) or implicit subsidies (Bahaj and Malherbe, 2018) that make the effect of capital standards on credit supply ambiguous or positive, we highlight the fact that tighter capital standards reduce the need for costly equity buffers, which lowers the marginal cost of credit reallocation.

The paper is organized as follows: Section 2 sets out the model. Section 3 analyzes equilibrium, explores efficiency properties, and calculates comparative static effects. Section 4 considers two extensions to show the robustness of our analysis. Section 5 concludes.

2 The Model

The model pictures banks that finance risky investments of firms, which are run by entrepreneurs with no private wealth. Investment is subject to firm-specific risk observed only at a later stage by the bank and the entrepreneur. If prospects turn out to be good, the firm can expand. Otherwise, the bank may prematurely liquidate the loan such that the firm is closed down. After absorbing losses, the bank collects liquidation values and uses these funds to finance expansion of firms with better prospects.

Capital is exclusively owned by investors. They allocate the wealth endowment partly to banks for lending to risky firms and partly to a safe alternative investment technology. Banks attract investor funds in the form of deposits and equity.

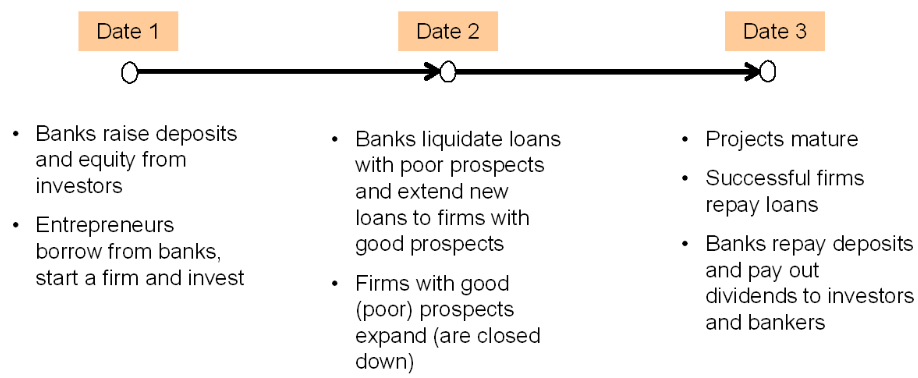

Figure 1: Time Line

Figure 1 illustrates the timing: (i) Investors allocate their endowment to deposits, bank equity, and the alternative technology. After receiving funds, banks provide loans to entrepreneurs who start a firm and invest (date 1); (ii) banks learn the idiosyncratic success probability of each borrower. They terminate bad loans and reallocate the proceeds to expanding firms (date 2); (iii) projects mature and contracts are settled (date 3).

2.1 Technologies

A firm invests in risky projects: At date 1, it can invest one unit of capital, which earns a return with an ex ante unknown success probability q, and zero else. At date 2, expansion investment is possible. It requires another unit of capital and promises an additional return $y_2 < y_1$ with the very same probability, and zero else. The inequality reflects decreasing returns. Investment risks are correlated within the same firm (i.e., either both projects succeed with the firm-specific probability q or fail with probability $1-q$), but are independent across firms.[2]

The success probability of each firm is drawn from a uniform distribution $q \sim U[0,1]$. It is observed at date 2 before the expansion project can be undertaken. Conditional on this information, projects with a low success probability may be terminated, which creates a liquidation cost $c \in [0,1]$ and releases funds of $1-c$ to be used elsewhere. Intuitively, assets are sold at a discount reflecting the firm specificity of capital goods, which are worth less in other uses.

Investors have access to an alternative technology with a safe gross return $r \geq 1$, which is long-term with no possibility to expand or liquidate in-between. Both technologies produce the same numeraire good. We impose the following parameter restriction:

Assumption 1 *Investment returns satisfy* $y_1 > 2r > y_2 > r$.

The uniform distribution implies $E(q) = 1/2$. On average, the expected return of the initial project exceeds the return of the alternative investment, whereas the reverse is true for the expected return on the expansion project. The latter would not be undertaken a priori and is worthwhile only if the firm's success probability q turns out to be high.

2.2 Banks

Banks are set up by investors and raise outside equity e and deposits d at date 1. They provide unit-size loans to a mass n of firms. To operate the bank, investors hire an insider with specific skills but no private wealth ('banker'). Involving the banker gives rise to an agency problem (see Section 2.5).

[2] The firm's type determines the success probability. Depending on the quality of the business models, both projects fail together with the same probability.

Credit Reallocation: With monitoring and loan collection skills, the bank observes the repayment (success) probability q of each of its borrowers at date 2.[3] Based on this information, it may (i) liquidate a loan if prospects are poor, $q \leq q_1$, and recover the share $1 - c$, (ii) continue with the initial loan if chances are better, $q_1 < q \leq q_2$, and (iii) grant an additional unit-size loan for expansion investment of firms with even better prospects, $q > q_2$. The cut-offs q_1 and q_2 are optimally chosen by the bank. Consistent with the idea of relationship lending, only the bank that financed the first project learns the borrower's type q and might provide additional credit. Noting Assumption 1, no other bank would finance expansion investment because the latter is unprofitable on average. The bank charges two distinct gross interest rates, namely, i_1 on initial and i_2 on expansion credit, which are determined in equilibrium.[4]

Banks attract outside equity and deposits only in the beginning. They cannot refinance at date 2 when reallocating credit. This assumption reflects our focus on reallocation in a Schumpeterian sense, which necessarily requires withdrawing capital from weak firms. The literature on bank regulation motivates such difficulties in refinancing and especially in issuing new equity with the opacity of bank assets in place, dilution costs or long delays (e.g., Repullo and Suarez, 2013). In the presence of capital requirements, the inability to raise equity makes it impossible to attract new deposits to finance new loans. Consequently, loan liquidation and new lending at date 2 are inherently linked as illustrated in Figure 2: Banks finance expansion loans, $(1 - q_2)\, n$, using liquidation proceeds $(1 - c)\, q_1 n$. The budget constraint for released and reinvested funds relates the cut-offs by

$$q_2 = 1 - (1 - c)\, q_1 \equiv q_2\,(q_1)\,, \quad q_2'\,(q_1) = -\,(1 - c) < 0. \tag{1}$$

Liquidating more aggressively by choosing a higher cut-off q_1 releases more capital for expansion loans and reduces the cut-off q_2. We conjecture $q_1 < q_2$ or, equivalently,

[3] We thus abstract from monitoring imperfections in the sense that the bank only observes a noisy signal about the borrower's type.

[4] We relax this assumption in an extension (see Section 4.2) and allow for firm-specific loan rates at the expansion stage, $i_2 = i_2\,(q)$. The resulting allocation is exactly the same in terms of liquidation, expansion, and investment.

$q_1 < 1/(2-c)$, and verify that it indeed holds in equilibrium. After reallocation, the loan portfolio consists of $(1-q_1)\,n$ initial plus $(1-q_2)\,n$ expansion loans. Liquidation shrinks the final loan volume to $n' = (1-q_1)\,n + (1-q_2)\,n = (1-cq_1)\,n < n$.

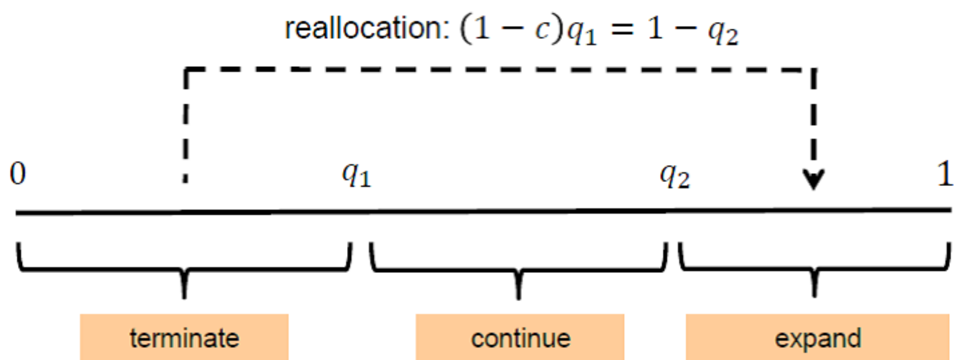

Figure 2: Credit Reallocation

Loan risks are uncorrelated, and bank profits are deterministic. Noting that banks extend initial and expansion loans, their earnings consist of gross interest i_1 repaid by a fraction $\bar{q}_1$ of the share $1-q_1$ of continuing firms plus gross interest i_2 repaid by fraction $\bar{q}_2$ of the share $1-q_2$ of expanding firms. These repayment (success) probabilities conditional on continuation and expansion are defined by

$$\bar{q}_1 = \frac{\int_{q_1}^{1} q dq}{1-q_1} = \frac{1+q_1}{2}, \quad \bar{q}_2 = \frac{\int_{q_2}^{1} q dq}{1-q_2} = \frac{1+q_2}{2}. \tag{2}$$

They are affected by the cut-offs according to $d\bar{q}_t/dq_t = 1/2$ and $d\left((1-q_t)\,\bar{q}_t\right)/dq_t = -q_t$ for $t \in \{1,2\}$. Taken together, bank profit equals interest earnings $\bar{\imath}n$ on a diversified credit portfolio net of deposit repayment with gross interest r required by investors (see Section 2.4 below):

$$\pi^b = \bar{\imath}n - rd, \quad \bar{\imath} \equiv \bar{q}_1 i_1 \cdot (1-q_1) + \bar{q}_2 i_2 \cdot (1-q_2)\,, \quad n = d + e. \tag{3}$$

Capital Regulation: Minimum capital requirements are a primary instrument of regulators and were tightened after the financial crisis (Basel III). The need for capital requirements is motivated by reasons outside the model. For example, they should provide a safety net ('buffer') to enhance financial stability and prevent bank failure, reduce risk shifting that emerges due to limited liability and guarantees (e.g., Furlong and Keeley, 1989; Rochet, 1992; Repullo, 2004), or allocate control rights to provide incentives for those managing the bank (Dewatripont and Tirole, 1994).

We therefore include capital requirements as the key regulatory constraint: The bank's capital ratio must never fall short of the minimum capital requirement k. Like in the Basel accords, the latter is defined in terms of risk-weighted assets. Since the bank has two (observable) asset classes, we normalize the risk weight for initial loans to one and introduce a relative risk weight w for expansion loans. We emphasize $w \leq 1$ because expansion loans are available only for the firms with the highest chances of success and repayment. Capital requirements for an initial and an expansion loan are equal to k and kw, respectively.[5]

At date 1, risk-weighted assets equal n and equity has to satisfy the capital constraint $e \geq kn$. Credit reallocation at date 2 importantly influences capital requirements: First, banks liquidate a share q_1 of loans and thereby incur a loss cq_1n. Since they cannot recapitalize, actual bank equity falls to $e - cq_1n$. Second, the loan volume shrinks in proportion to this loss despite new expansion loans, which reduces required equity by $-kcq_1n$. Third, credit reallocation also affects risk-weighted assets since expansion credit is assigned a different risk weight w. Savings in risk-weighted assets and, in turn, regulatory capital amounts to $-k(1-w)(1-c)q_1n$. At date 1, a bank anticipates these effects and raises an equity buffer in excess of the regulatory minimum kn:

$$e \geq kn + bq_1n, \quad b \equiv \max\left\{(1-k)c - k(1-w)(1-c), 0\right\}. \tag{4}$$

The capital buffer is b per liquidated loan; it is strictly positive, except for degenerate

[5] After the initial credit is given, banks learn a firm's individual success probability. We assume that such information in the internal lending relationship is not verifiable to outside parties. Risk weights are thus conditional only on the date of the credit decision and cannot reflect subsequent information. Indeed, the literature emphasizes that bank regulation can only be based upon information that is verifiable in court, see Freixas et al. (2007) and Eisenbach et al (2016), for example.

parameter values. Raising a buffer of bq_1n, which is voluntary ex ante, allows banks to liquidate up to q_1n loans at date 2 without violating capital requirements.

A special case of (4) with comparable implications is a solvency constraint with $k = 0$. Since banks cannot continue with negative equity, reallocation requires positive equity $b = c$ per liquidated loan, giving a capital constraint $e \geq cq_1n$.

2.3 Firms and Entrepreneurs

There is a mass 1 of entrepreneurs with no private wealth. Each of them may start a firm with an initial project at date 1 and a potential expansion project at date 2. Each project requires investment of 1 financed by bank credit with gross interest i_1 and i_2. Entrepreneurs choose at date 1 between starting a firm and inactivity.

The firm is risky and its projects succeed with the firm-specific probability $q \sim U[0,1]$ observed only after initial investment at date 2. The entrepreneur anticipates that her firm may secure additional credit and expand (if $q < q_1$) or be closed down if the loan is liquidated ($q < q_1$). She would always want to continue because continuation promises a positive expected profit $q(y_1 - i_1)$, while liquidation yields nothing. Expected firm profit equals

$$\pi^f = \int_{q_1}^{q_2} q(y_1 - i_1)\, dq + \int_{q_2}^{1} q(y_1 - i_1 + y_2 - i_2)\, dq. \tag{5}$$

Noting symmetry, this expression is equivalent to

$$\pi^f = \bar{y} - \bar{\imath}, \quad \bar{y}(q_1) \equiv \bar{q}_1 y_1 \cdot (1 - q_1) + \bar{q}_2 y_2 \cdot (1 - q_2), \tag{6}$$

where $\bar{\imath}$ denotes expected interest payment as in (3). Expected output $\bar{y}$ is a measure of firm-level productivity. The marginal effect of a higher liquidation cut-off highlights the effects of reallocation on expected firm output. Using (1-2) gives

$$\bar{y}'(q_1) = (1 - c)\, q_2 y_2 - q_1 y_1, \quad \bar{y}''(q_1) = -(1 - c)^2 y_2 - y_1 < 0. \tag{7}$$

Loan liquidation releases funds that finance expansion investment of better performing firms. By (1), $\bar{y}'(0) = (1 - c)\, y_2 > 0$. Raising the liquidation rate from very low levels clearly boosts expected output because low output projects $q_1 y_1$ are replaced by projects with high expected output $(1-c)\, q_2 y_2$ net of the liquidation cost. With an increasing liquidation rate, marginal costs of reallocation rise and marginal gains fall. Up to the limit $q_1 = 1/(2-c)$, where $q_1 = q_2$, firm-level output decreases in the liquidation rate, $\bar{y}'(q) = q_1 [(1-c)\, y_2 - y_1] < 0$ since $y_2 < y_1$ by Assumption 1.

Entrepreneurs are heterogeneous in the effort needed to set up a firm:

Assumption 2 *Entrepreneurial talent is uniformly distributed among all prospective entrepreneurs,* $h \sim U[0,1]$. *An entrepreneur's effort cost* $\omega(h)$ *rises with declining talent,* $\omega'(h) > 0$, *and satisfies Inada conditions* $\lim_{h\to 0} \omega(h) = 0$ *and* $\lim_{h\to 1} \omega(h) = \infty$.

High talent corresponds to low h and is associated with a low effort cost $\omega(h)$. Welfare of type h equals expected firm profit net of the effort cost, $v^e(h) \equiv \pi^f - \omega(h)$, if she starts a firm, and is zero else. The pivotal type n is determined by $\pi^f = \omega(n)$. Given the uniform talent distribution, a share n of entrepreneurs starts a firm and invests.

2.4 Investors

Asset Income: Investors are endowed with wealth $I > 1$. At date 1, they allocate their wealth between deposits d, bank equity e, and a long-term, alternative investment opportunity A earning a fixed return $r \geq 1$. Since assets are perfect substitutes, investors require a return on equity and deposits equal to r, giving a perfectly elastic supply at this rate. As bank shareholders, investors receive dividends on their share z of profit π^b. This share is set to provide incentives for the banker, whom they hire to run the bank. Dividends worth $z\pi^b$ must at least match the required return re. Asset income is

$$\pi^i = z\pi^b + rd + rA, \quad I = e + d + A. \tag{8}$$

In equilibrium with no arbitrage, $z\pi^b = re$, so that investor welfare is equal to $\pi^i = rI$.

Agency Problem: Operating a bank requires a 'banker' (insider) who has no wealth and a zero outside option. To prevent opportunistic behavior of the insider, equity investors need to solve a governance problem. A banker can always leave after diverting a part x of interest earnings. We follow Ellingsen and Kristiansen (2011) and assume that owners detect diversion with probability p, in which case they are able to confiscate diverted funds. Otherwise, the banker is not detected and keeps diverted earnings.

The insider will divert earnings only up to bank profit $\pi^b = \bar{\imath}n - rd$. We rule out a larger diversion $x > \pi^b$, which violates the 'hard' claims of depositors, for two reasons: In general, diverting more than π^b causes insolvency. Bankruptcy procedures and potential criminal investigations would significantly increase the detection probability and expose the banker to potentially large non-pecuniary penalties.[6] Moreover, bank regulators have an especially strong position once an institution violates regulatory standards or is insolvent. They may take over control and immediately close the bank, which makes it impossible to divert more earnings.[7] For these reasons, violating claims of depositors is unprofitable or even unfeasible for the banker. This limits diversion of earnings to $x \leq \pi^b$. If the banker diverts at all, she takes the maximum amount and chooses $x \in \{0, \pi^b\}$.

To prevent diversion, owners must offer the banker a rent. They offer the banker a share $1 - z$ of profits, which needs to satisfy a *no-diversion constraint*,

$$(1 - z) \cdot \pi^b \geq (1 - p) \cdot \pi^b \quad \Leftrightarrow \quad z \leq p. \tag{9}$$

The banker only receives the rent if she does not divert, $x = 0$. After compensating

[6] La Porta et al. (2006) point to strong evidence that laws mandating disclosure and facilitating private enforcement through liability rules benefit stock markets. In the spirit of our assumptions, the law and finance literature distinguishes between measures for creditor protection and investor/shareholder protection, see the review of La Porta et al. (2013). We specifically assume that violating the rights of senior claims (deposits) which get served first in a bankruptcy, entails more severe consequences than violating junior claims which are protected less and are left with residual profits only.

[7] An example is the role of the FDIC in the U.S., which takes over a critically undercapitalized bank to protect depositors' interest and initiates resolution procedures. See Ragalevsky and Ricardi (2009) and Vij (2019) for an extensive discussion of the role of the FDIC in resolving insolvent banks.

bankers, outside shareholders receive dividends worth $z\pi^b$ which must at least match the required return on equity,

$$S^o = z\pi^b - re \geq 0. \tag{10}$$

Free entry eliminates any excess return on equity and reduces the surplus to zero.

Eventually, we rule out a prohibitively high agency cost of equity:

Assumption 3 *Returns and detection probability satisfy* $y_1/2 > r + rk(1-p)/p$.

This condition ensures that the initial project is profitable if it is financed by a bank that satisfies the capital standard k and promises the insider the lowest possible share $1-p$. The existence of agency costs related to $p < 1$ requires a slightly stronger restriction on the return of the initial project than Assumption 1, which states $y_1/2 > r$.

2.5 Equilibrium

Figure 3 summarizes the aggregate flow of funds in this model at each date.

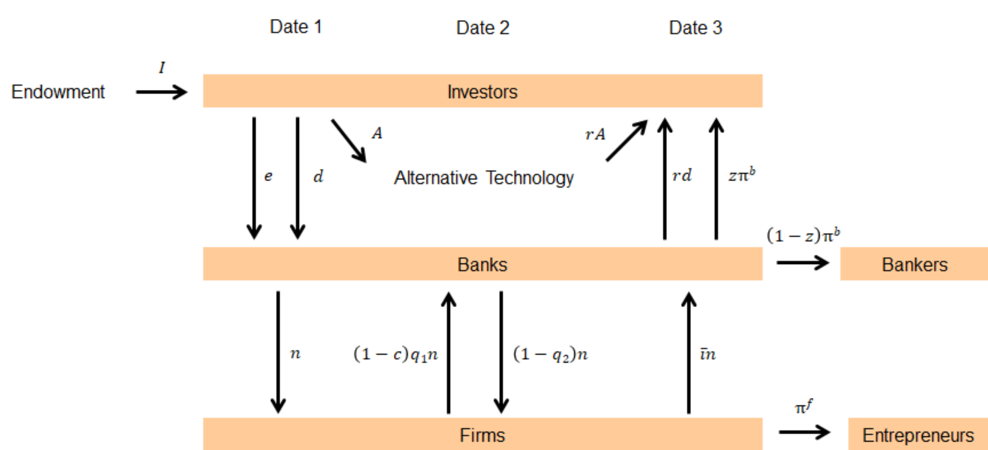

Figure 3: Aggregate Flow of Funds

In equilibrium, aggregate output equals aggregate spending. Initial firm investment n results from entry and bank lending. Each firm produces y_1 with probability $\bar{q}_1(1-q_1)$

and y_2 with probability $\bar{q}_2(1-q_2)$, giving expected output $\bar{y}$ as defined in (6). In addition, investors allocate some funds to alternative investments A. Aggregate output is

$$Y = \bar{y}(q_1)\,n + rA. \tag{11}$$

Income equals the sum of expected firm profits, rents of bankers, and investor profits,

$$\Pi = \pi^f n + (1-z)\,\pi^b + \pi^i, \tag{12}$$

and is spent on the numeraire good. With expected interest payments on firm credit defined in (3), bank and firm profits are $\pi^b = \bar{\imath}n - rd$ and $\pi^f = \bar{y} - \bar{\imath}$. Using (9-10) yields the income expenditure identity $\Pi = Y$. Aggregate demand is equal to total income Π and matches aggregate supply Y.

3 Equilibrium Analysis

This section characterizes two allocations, namely, a first-best benchmark and a constrained equilibrium, in which banks face capital regulation and agency problems, and characterizes welfare properties. Subsequently, a comparative static analysis informs about targeted policy interventions and institutional changes that mitigate frictions and strengthen the productivity-enhancing role of banking by facilitating reallocation.

3.1 First Best

We establish a first-best benchmark without an agency problem and capital regulation. The allocation follows from welfare maximization subject to a resource constraint. Welfare equals aggregate surplus. Each entrepreneur expects $v(h) = \pi^f - \omega(h)$. Collecting all n entrants yields total welfare of entrepreneurs, $\pi^f n - \Omega(n)$, where $\Omega(n) \equiv \int_0^n \omega(h)\,dh$ denotes total effort cost in preparing entry. Since welfare of other agents is equal to their income, aggregate welfare is $V = \Pi - \Omega(n)$.

Aggregate income is $\Pi = \bar{y}(q_1) n + r(I-n)$ by the income expenditure identity and only depends on liquidation and entry but not on the capital structure of banks. The maximization problem is

$$V = \max_{q_1,n} \Pi - \Omega(n). \tag{13}$$

Using (7), the first-best allocation q_1^* and n^* must satisfy optimality conditions

$$\frac{dV}{dq_1} = \bar{y}'(q_1^*) n = [(1-c) q_2(q_1^*) y_2 - q_1^* y_1] n = 0, \quad \frac{dV}{dn} = \bar{y}(q_1^*) - r - \omega(n^*) = 0. \tag{14}$$

Optimal liquidation maximizes expected firm output by equalizing marginal gains and costs. Solving the first-order condition together with $q_2 = 1-(1-c) q_1$ yields the first-best cut-offs for loan liquidation and new lending:

$$q_1^* = \frac{(1-c) y_2}{y_1 + (1-c)^2 y_2}, \quad q_2^* = \frac{y_1}{y_1 + (1-c)^2 y_2}.$$

They satisfy $q_1 < q_2 < 1$ and $q_1 < 1/(2-c)$ on account of Assumption 1. Only the most successful among all continuing firms receive capital for expansion investment. With optimal entry, the surplus of the marginal entrant n^*, equal to expected output net of the cost of capital, just covers her effort cost.

3.2 Constrained Equilibrium

We solve the model by backward induction. We first derive optimal liquidation and credit reallocation, conditional on previously set interest rates. Then we proceed with initial decisions on capital structure and contracts, anticipating subsequent results.

Reallocation: Once the bank observes the repayment probability of all loans, it reallocates credit from firms with poor prospects to those with a high chance of success. Optimal reallocation with cut-offs q_1 and $q_2 = q_2(q_1)$ maximizes the bank's expected interest earnings $\bar{\imath}$ subject to the regulatory constraint (4). Denoting the multiplier by θ, the bank solves

$$\bar{\imath} = \max_{q_1} \ \bar{q}_1 i_1 \cdot (1-q_1) + \bar{q}_2 i_2 \cdot (1-q_2) + \theta [e - kn - b q_1 n] / n. \tag{15}$$

Optimality requires $-q_1 i_1 - q_2 i_2 q_2' (q_1) = \theta b$. Liquidating the marginal loan reduces expected interest earnings by $q_1 i_1$ and allows for an expansion credit with earnings $(1-c) q_2 i_2$. In addition, liquidation tightens the regulatory constraint. Using $q_2 = 1 - (1-c) q_1$ gives the optimal cut-offs for liquidation and new lending

$$q_1 = \frac{(1-c) i_2 - \theta b}{i_1 + (1-c)^2 i_2}, \quad q_2 = \frac{i_1 + (1-c) \theta b}{i_1 + (1-c)^2 i_2}. \tag{16}$$

The cut-offs depend on relative interest rates on initial and expansion loans and on the recovery rate $1-c$. Interest rates were already determined at date 1 and are taken as given by banks at this stage. If the capital requirement binds ($\theta > 0$), banks liquidate fewer loans because liquidation erodes the equity buffer.

Capital Structure: At date 1, investors provide equity, hire a banker and offer an incentive pay. After attracting deposits and equity, the bank extends loans. Formally, the financing contract of the bank maximizes the surplus of shareholders, subject to the no-diversion constraint for the banker:

$$S^o = \max_{z,e,n} z\pi^b - re \quad s.t. \quad p \geq z. \tag{17}$$

Optimality with respect to the insider's share z implies a binding no-diversion constraint, $z = p$.[8] Owners offer no more than the minimum share that suffices to prevent diversion of earnings. Noting $\pi^b = (\bar{\imath} - r) n + re$ and $d\bar{\imath}/de = \theta/n$ by (15), the shadow price of equity is strictly positive and satisfies $p\theta = (1-p) r$.[9] Therefore, the regulatory constraint in (15) binds, $e = (k + bq_1) n$. Banks raise a capital buffer that just covers anticipated losses during the liquidation process.

Banks expand lending to maximize shareholder surplus. Using $z = p$, optimality requires $dS^o/dn = p [\bar{\imath} - r - n \cdot d\bar{\imath}/dn] = 0$. By (15), a larger loan volume reduces expected interest earnings by $d\bar{\imath}/dn = -\theta e/n^2$. Using this together with the binding capital constraint implies that banks expand lending until interest earnings in equilibrium just match

[8] Noting $S^o = \max z\pi^b - re + \mu (p - z) \pi^b$, optimality $dS^o/dz = (1-\mu) \pi^b = 0$ gives $\mu = 1$ and $z = p$.

[9] Optimal equity satisfies $dS^o/de = [z + \mu (p - z)] (r + \theta) - r = 0$. Using $z = p$ gives $p\theta = (1-p) r$.

refinancing costs at the margin,

$$\bar{\imath} = \bar{r} + \theta b q_1, \quad \theta = \frac{1-p}{p} \cdot r, \quad \bar{r} \equiv r + \theta k. \tag{18}$$

$\bar{r}$ denotes the funding costs per loan if the bank's capital ratio is equal to the regulatory minimum k. The shadow price θ, which depends on the probability p of detecting diversion, reflects the differential cost of equity relative to deposits. We also refer to θ as an 'equity premium'. To see this, one can use (18) to express bank profit $\pi^b = \bar{\imath} n - rd = (r + \theta) e$.[10] Competition among banks eliminates any rent on outside equity such that investors earn no more than the required return, $S^o = 0$ or, equivalently, $z\pi^b = p(r+\theta)e = re$. Insiders keep a rent $(1-z)\pi^b = (1-p)(r+\theta)e = \theta e$.

As long as bankers can keep diverted earnings with a positive probability $1-p$, shareholders must cede a profit share to prevent them from misusing funds. As a result, equity is more expensive than deposits. Banks must earn a larger profit to guarantee owners, after compensating bankers, the required return r. They thus economize on using equity until the capital constraint binds. If diversion of funds could always be detected without costs ($p \to 1$), no incentive pay would be needed, and differential costs of equity would vanish ($\theta \to 0$). No distinction would be left between equity and debt financing. The constraint would be slack and any capital ratio $e/n \geq k + bq_1$ would be optimal, reflecting the Modigliani-Miller irrelevance theorem.

Credit Contract: Our analysis pictures a competitive loan market. This assumption ensures a credit contract undistorted by competitive frictions and allows us to focus on distortions due to the combination of an agency problem and regulatory constraints. We thus abstract from market power, which plays some role in relationship banking (e.g., Petersen and Rajan, 1995) and may influence loan rates and ultimately distort reallocation.[11]

[10]Substitute $\bar{\imath} = \bar{r} + \theta b q_1$ into $\pi^b = (\bar{\imath} - r)n + re$ and use $e = (k + bq_1)n$ to get $\pi^b = (r+\theta)e$.

[11]In this spirit, a bank might have some market power when extending an expansion loan at date 2 because it is the only lender observing the borrower's type. It may thus appropriate the full surplus

Loan rates are determined in equilibrium by the break-even condition of competitive banks. In other words, the credit contract is designed in a way that maximizes expected firm profit $\pi^f = \bar{y} - \bar{\imath}$. A bank could otherwise steal business from its rivals by offering more attractive rates that leave firms with even higher profits. Expected interest $\bar{\imath}$ the matches refinancing costs. In addition, the rate structure i_1 and i_2 needs to be such that the induced liquidation rate in (16) maximizes firm profit. To determine the optimal rate structure, we first find the liquidation rate that maximizes expected firm profit. In a second step, we solve for the interest rates that support the optimal liquidation rate. Substituting the bank's break-even condition (18) yields the reduced problem, in which expected firm profit exclusively depends on the cut-offs q_1 and $q_2(q_1)$:

$$\pi^f = \max_{q_1} \ \bar{y}(q_1) - \bar{r} - \theta b q_1, \quad \bar{y}(q_1) \equiv \bar{q}_1 y_1 (1 - q_1) + \bar{q}_2 y_2 (1 - q_2). \tag{19}$$

Liquidation is optimal if $\bar{y}'(q_1) - \theta b = -q_1 y_1 - q_2 y_2 q_2'(q_1) - \theta b = 0$. It equalizes marginal expected earnings with the marginal cost of the equity buffer that is needed to absorb liquidation losses. Using (1) yields the optimal cut-offs for liquidation and lending,

$$q_1 = \frac{(1-c) y_2 - \theta b}{y_1 + (1-c)^2 y_2}, \quad q_2 = \frac{y_1 + (1-c)\theta b}{y_1 + (1-c)^2 y_2}. \tag{20}$$

As in the first best, the assumption $y_2 < y_1$ ensures $q_1 < 1$, and $q_1 < q_2$ holds a fortiori.

The loan rates i_1 and i_2 are set at date 1 and affect the bank's subsequent liquidation decision at date 2 according to (16). To induce the optimal liquidation rate q_1 given above, interest rates have to satisfy

$$i_2 = \frac{q_1 i_1 + \theta b}{(1-c) q_2}. \tag{21}$$

Given this ratio, competitive banks proportionately scale down the level of loan rates to shift profits to entrepreneurs until they hit break even. Appendix A derives in (A.2) and (A.3) closed-form solutions for loan rates and proves $y_1 > i_1$ as well as $y_2 > i_2$. With

by setting a high interest rate on the expansion loan. Competition ex ante, in turn, would drive down the interest rate on the first loan to ensure zero bank profit. Such a rate structure will affect credit reallocation.

these rates, both initial and expansion projects are privately profitable on account of Assumption 3, which coincides with $y_1 > 2\bar{r}$. A successful firm fully repays the outstanding loan.

Entry: Entrepreneurs enter as long as $v^e(h) = \pi^f - \omega(h) \geq 0$, that is, their expected surplus is non-negative. Since banks just break even, firms appropriate the entire joint surplus, $\pi^f = \bar{y}(q_1) - \bar{r} - \theta b q_1$. The marginal entrant determines initial investment

$$\omega(n) = \bar{y}(q_1) - \bar{r} - \theta b q_1. \tag{22}$$

Expected output must cover bank funding costs plus the effort cost of preparing entry.

Welfare: To characterize the welfare properties of the constrained market equilibrium, we evaluate the optimality conditions in (14) at the market allocation which results in:

Proposition 1 ***(Efficiency)*** *In market equilibrium, credit reallocation and investment by firm entry are lower than in the first-best allocation, $q_1 < q_1^*$ and $q_2 > q_2^*$, as well as $n < n^*$. In the absence of any agency costs ($p \to 1$, $\theta \to 0$), reallocation and entry in market equilibrium would be first-best.*

Proof. Evaluating the welfare derivatives (14) in market equilibrium yields

$$\frac{dV}{dn} = \bar{r} + \theta b q_1 - r = \theta \cdot (k + b q_1) > 0, i \tag{23}$$

$$\frac{dV}{dq_1} = [(1-c)\, q_2 y_2 - q_1 y_1]\, n = \theta \cdot b > 0.ii \tag{24}$$

Equation (i) follows by substituting the free-entry condition (22) into (14) and using (18) for $\bar{r}$. Equation (ii) uses the first-order condition of (19), $\bar{y}'(q_1) = \theta b$. Stimulating reallocation and entry would yield welfare gains and move the economy closer to the first best. If $\theta = 0$, the market allocation would satisfy the conditions (14) for a first-best allocation. The capital constraint would not be binding. Any equity ratio $(k + b q_1) \leq e/n \leq 1$ would be optimal. ■

Agency costs make equity capital more costly than deposits and create an incentive for banks to economize on the expensive capital buffer. Consequently, banks tend to avoid expected liquidation losses to some extent and allow marginal firms to continue in spite of poor prospects. Misallocation is prevalent whenever the differential cost of equity reflected in θ is high and reallocation requires a large capital buffer b.

Too little reallocation and expansion financing also affect the entry margin. The differential cost of using equity is shifted to firms via higher loan rates. Furthermore, expected firm output $\bar{y}(q_1)$ declines because of reduced credit reallocation. As a result, declining firm profit discourages entry into the entrepreneurial sector. More capital is allocated to the relatively less productive alternative technology.

The focus of our analysis is (mis)allocation of credit that emerges due to the combination of regulatory or solvency constraints and agency costs of equity. 'Zombie lending', that is, the continued financing of projects with negative net present value (NPV), is an extreme form of misallocation. We show in Appendix D that 'Zombie lending' indeed exists with reasonably realistic parameters and blocks expansion of firms with profitable investment opportunities. But even if 'Zombie lending' does not exist, the Schumpeterian role of banks can generate important welfare gains by moving credit from weak firms with low NPV projects to stronger ones with high NPV projects.

Finally, the general model nests several special cases. First, if equity is no more expensive than deposits because contracts can be perfectly enforced ($p = 1$ such that $\theta = 0$), the bank always raises a sufficiently large capital buffer, without inflating its refinancing costs. The regulatory constraint is slack, leading to first-best investment. The capital structure is irrelevant up to the regulatory constraint. Second, the required buffer might fall to zero, $b = 0$, if capital requirements k are tight and the risk weight of expansion loans w is very low, see (4).There is no effect of liquidation on the use of equity, and the cut-offs q_1 and q_2 are first-best. The scenario points to high capital requirements and a low equity premium being substitutes as they both foster reallocation. However, the agency cost of equity raises borrowing costs of firms from r to $\bar{r}$, which is quite high with tight capital standards, and discourages entry, $n < n^*$. Third, in a 'rigid economy' where either equity or liquidation are very expensive, $\theta b \rightarrow (1-c)\, y_2$, banks consider credit reallocation too costly, giving $q_1 = 0$. This case describes a poor institutional environment where banks cannot fulfill their 'Schumpeterian role'.

3.3 Comparative Statics

This section analyzes how investment and capital productivity depend on four key parameters. Appendix B documents detailed calculations.

Capital Regulation: Bank regulators may impose tighter minimum capital standards k or reduce the risk weight w on expansion loans to facilitate reallocation and to ultimately boost aggregate capital productivity. The Basel accords require that risk weights should reflect the default probability of borrowers, either based on a firm's rating or calculated in using the bank's internal models. Credit risk associated with expansion loans is lower since only the most successful firms receive such loans.

Since bank equity is more expensive than deposits, the key impact derives from changes in the capital buffer in (4) that is needed to cover anticipated liquidation losses:

$$db = (1-c)\, k \cdot dw - [c + (1-w)\,(1-c)] \cdot dk. \tag{25}$$

A higher capital standard ($dk > 0$) has two effects. Liquidating $q_1 n$ loans requires a buffer $cq_1 n$. Since it also shrinks the balance sheet and required equity of the bank, the capital constraint relaxes in proportion to k. This balance sheet effect, which reduces the required buffer to $(1-k)\, cq_1 n$, is stronger whenever the standard is already high, leading to savings of $db = -c \cdot dk$ per liquidated loan. In addition, reallocation shifts the composition of the credit portfolio to expansion loans with a lower risk weight $w \leq 1$, which further lowers the buffer in proportion to k. Similarly, a lower relative risk weight ($dw < 0$) relaxes the regulatory constraint and allows for a smaller buffer.

For these reasons, a higher capital standard and a lower risk weight for expansion credit both reduce the equity buffer. These savings facilitate liquidation and reallocation as noted in (B.1), $dq_1 > 0$. The size of this effect is proportional to the differential cost of equity θ. Banks thus liquidate bad loans more aggressively and, by $d(1-q_2) = (1-c) \cdot dq_1$, provide expansion credit to more firms.

More active liquidation terminates investment in states with low success probabilities and shifts funds to states with high chances of success. In a cross-section, credit reallocation shifts investment from rather unproductive to the most productive firms, thereby boosting expected output per firm by $d\bar{y} = \theta b \cdot dq_1 > 0$, see (B.2). Productivity would only be unaffected in a frictionless economy with $\theta b \to 0$. In this case, the credit contract would maximize expected output so that a small variation in reallocation could not enhance output any further.

Aggregate investment reflects reallocation and entry. The marginal entrant is indifferent between entrepreneurship and inactivity, giving rise to the free-entry condition $\pi^f = \omega(n)$. Rising expected firm profits thus encourage entry and initial investment. Competition forces banks to offer borrowers the most favorable credit terms, leading to firm profits of $\pi^f = \max_{q_1} \bar{y}(q_1) - \bar{r} - \theta b q_1$. Using the Envelope theorem gives $d\pi^f = -\theta \cdot dk - \theta q_1 \cdot db$. A lower risk weight on expansion credit reduces the cost of the equity buffer, which lowers loan rates and raises firm profit. A higher capital standard inflates borrowing costs of banks because total equity rises in spite of a smaller buffer b. On net, expected firm profit shrinks, $d\pi^f = -\theta[1 - q_1 + w(1-c)q_1] \cdot dk < 0$, which discourages entry.

Capital productivity, which is defined as total output per unit of aggregate investment Y/I, is of particular interest. Using the resource constraint $A = I - n$, output in (11) is $Y = (\bar{y} - r)n + rI$. With a fixed endowment, productivity changes along with output, $dY = n \cdot d\bar{y} + (\bar{y} - r) \cdot dn$, which reflects changes in average firm output $\bar{y}$ and the investment allocation n between the entrepreneurial and residual sectors. Assumption 1 implies $\bar{y} > r$. Expected firm output is larger than the return on alternative investment.

In consequence, shifting investment from the residual to the entrepreneurial sector boosts capital productivity. The two channels may reinforce or offset each other.

Risk differentiation unambiguously boosts aggregate productivity. Reducing the risk weight for expansion loans ($dw < 0$) implies that banks need to rely less on costly equity, which mitigates distortions (see Proposition 1) by stimulating both reallocation and entry. As a result, average firm output $\bar{y}$ increases and initial investment n shifts to the more productive entrepreneurial technology. Total output Y and, in turn, capital productivity rise. Tighter capital standards ($dk > 0$), in contrast, have a more ambiguous effect. They mitigate distortions at the reallocation margin but magnify them at the entry margin, that is, they stimulate reallocation but impair entry. While firm-level productivity improves, total bank equity $e = (k + bq_1)\,n$ is unambiguously higher, which raises the refinancing costs of banks leading to higher loan rates and lower firm profits. The latter shifts initial investment to the less productive alternative technology. The productivity-enhancing reallocation effect prevails as long as entry is not too elastic.

Proposition 2 ***(Capital Regulation)*** *Imposing a tighter capital standard ($dk > 0$) and differentiating risk weights ($dw < 0$) boost reallocation and average firm output. Differentiation stimulates entry investment and raises aggregate capital productivity. A higher capital standard discourages entry. It raises productivity if entry is relatively inelastic.*

Proof. Appendix B. ■

The real effects of bank regulation hinge on the differential cost of equity. In a frictionless economy where contracts were perfectly enforced and there were no agency costs ($p \to 1$ such that $\theta \to 0$), the costs of equity and deposits would be the same. The capital structure of banks would be largely irrelevant, and regulation would not affect reallocation, average firm output and productivity.[12]

[12] In Appendix B, the size of all effects is proportional to θ. The impact of regulatory changes on liquidation rate, average firm output, entry, and aggregate productivity vanishes for $\theta \to 0$.

Conventional wisdom suggests that capital requirements reduce the supply of credit. Recent research such as Bahaj and Malherbe (2018) and Begenau (2019) finds, in contrast, that tightening capital requirements might actually increase lending. In a sense, our results reconcile these views by highlighting two opposing channels. First, tighter capital standards reduce entry and, thereby, first-round lending as in the conventional view. Second, tighter standards boost reallocation and, thereby, stimulate credit supply for expansion investment. The intuition rests on a balance sheet effect: Liquidation shrinks the total loan volume which relaxes capital requirements so that a smaller capital buffer is needed. These savings are larger if capital standards are higher. Given that equity capital is more costly, a smaller required buffer facilitates liquidation. Via this channel, higher capital standards stimulate reallocation and credit supply for expansion investment. The mechanism is specific to credit reallocation and differs form the general equilibrium and forced safety effects emphasized in other papers.

Agency Costs: The agency problem is the source of the differential costs of equity relative to deposits, which creates an incentive for high bank leverage. The magnitude of these costs depend on the detection probability p of outside equity investors, see (18). It may reflect bank-specific and institutional determinants. Tighter reporting and accounting standards and antidirector rights better protect shareholders and may be associated with a higher detection probability, thereby reducing agency costs. A higher detection probability unambiguously decreases the equity premium:

$$d\theta = -\left(r/p^2\right) \cdot dp. \tag{26}$$

The bank's total required equity is $e = (k + bq_1)\, n$, consisting of regulatory and buffer capital, and creates differential funding costs θe. A lower equity premium ($d\theta < 0$) reduces the cost of the capital buffer $\theta b q_1 n$ and thereby facilitates credit reallocation. The liquidation rate q_1 rises and the cut-off for expansion lending q_2 falls, (see B.1). Expected firm output rises with more reallocation, $d\bar{y} > 0$. Moreover, the lower cost of equity reduces loan rates, increases expected firm profit by $d\pi^f = -(k + bq_1) \cdot d\theta$ and, in turn, stimulates entry. Aggregate capital productivity rises at both margins. The comparative static analysis in Appendix B establishes

Proposition 3 ***(Agency costs)*** *A reduction of differential costs of bank equity ($d\theta < 0$) on account of improved corporate governance ($dp > 0$) boosts reallocation, average firm output and entry. Aggregate capital productivity rises.*

Proof. Appendix B. ■

Liquidation Costs: Credit reallocation leads to liquidation losses of banks and shrinks equity capital. These losses, reflected in recovery rates $1 - c$, vary substantially across countries, for bank-specific reasons as well as institutional factors such as quality of bankruptcy laws.[13] We briefly point to the consequences of such differences for banks and the real economy. First, a higher liquidation cost c raises the necessary equity buffer by $db = (1 - wk) \cdot dc > 0$. Since the buffer is expensive and banks can extract lower liquidation values, they reduce the liquidation rate q_1. Expected firm output declines, not only because of reduced reallocation, but also since larger liquidation losses directly shrink the volume of reallocated credit, see (B.2). For both reasons, expected firm profit and entry decline. Aggregate capital productivity falls. Appendix B gives details.

Policy reform and changes in the institutional environment can strengthen the 'Schumpeterian role' of the banking sector and shift the market equilibrium closer to an efficient allocation. Bank capital regulation, measures that make equity more available and less expensive for banks, and more efficient bankruptcy procedures that lower the cost of loan liquidation, are among the options. For example, regulators may impose tighter minimum capital standards or reduce the risk weight on expansion loans with lower credit

[13]For the U.S., Acharya et al. (2007) report a mean loan recovery rate of 81 percent for non-financial corporations (1982-1999), and Khieu et al. (2012) find a similar value of 84 percent for large syndicated loans (1987-2007). Grunert and Weber (2009) report a 73 percent rate for German firms. A recovery rate of only 48 percent is found by Caselli et al. (2008) in a large sample of Italian SME (1990-2004).

risk. Indeed, the Basel accords require that risk weights should more closely reflect the default probability of borrowers. Differentiating risk weights thus fosters credit reallocation to the most productive firms and ultimately boosts aggregate capital productivity. Institutional improvements like better reporting and accounting standards and legal protection of equity investors, could limit management discretion in diverting funds, relax incentive constraints of bankers and reduce agency costs that subtract from the return on equity capital. Improving access to equity capital at lower cost could strengthen the productivity-enhancing role of banking.

4 Extensions

This section studies two alternative financing contracts. First, we allow for direct finance by investors who cannot monitor or reallocate credit. We demonstrate under which conditions firms choose bank credit or directly borrow from investors, thereby identifying potential welfare gains of financial intermediation. Second, banks may exploit emerging firm heterogeneity at date 2 and charge different interest rates on expansion loans depending on firm risk. We show that such contracts implement the same allocation.

4.1 Direct Finance

Delegated monitoring is one of the key justifications of financial intermediation as demonstrated in the seminal contribution of Diamond (1984). In our framework, the existence of banks owes to their specific monitoring and loan collection skills, allowing them to observe a firm's success probability q in the interim period. To characterize the value of intermediation, we compare banking with direct financing of firms by investors who do not possess such skills and, thus, cannot observe a firm's type q. Entrepreneurs with poor prospects have no incentive to reveal their type since they would lose if the loan were terminated. On the contrary, as long as expansion investment promises a profit, $y_2 > i_2$, all entrepreneurs have an incentive to signal good quality. As a result, there will be no credit reallocation, $q_1 = 0$ and $q_2 = 1$, whenever firms directly borrow from investors. All firms continue, and no firm gets a chance for expansion investment.

Investors can allocate funds to the alternative investment technology with return r. Given a firm's ex ante success probability $E(q) = 1/2$, they must charge a loan rate $i_1 = 2r$. At this rate, the first investment is profitable, $y_1 > 2r$, but expansion investment is not, $y_2 < 2r$ (see Assumption 1). Firms therefore invest one unit and earn expected profit $\pi^f|_{q_1=0} = E(q)(y_1 - i_1) = y_1/2 - r$. Direct finance always dominates a similar, simple credit contract since banks are subject to capital requirements, must raise at least some costly equity and, thus, require a higher interest rate to provide the loan, $i_1 = 2\bar{r} > 2r$. Consequently, financial intermediation can only exist as long as banks are able to offer more attractive contracts with the opportunity to expand, thereby raising expected firm earnings from $\bar{y}(0)$ to $\bar{y}(q_1)$. The following proposition compares a firm's profit from direct finance, $\pi^f|_{q_1=0}$, to its profit π^f when using bank credit with potential expansion financing, and establishes:

Proposition 4 *(**Banks versus Direct Finance**) Bank credit offers a larger expected firm profit than direct finance if*

$$q_1^2 \frac{y_1 + (1-c)^2 y_2}{2} \geq \theta k, \tag{27}$$

where the cut-off q_1 is given by (20). Firms prefer to borrow from banks. Relative to direct finance, bank credit offers potential expansion investment and boosts business creation.

Proof. Firm profit is larger with bank credit if $\pi^f = \bar{y}(q_1) - \bar{r} - \theta b q_1 \geq \pi^f|_{q_1=0}$. Use (2) together with $1 - q_2 = (1-c) q_1$, and rewrite expected firm output in (6) as $\bar{y}(q_1) = y_1/2 + q_1 [(1+q_2)(1-c) y_2 - y_1 q_1]/2$. Note $\pi^f|_{q_1=0} = y_1/2 - r$ and get

$$\nabla\pi^f \equiv \pi^f - \pi^f|_{q_1=0} = \frac{q_1}{2} [(1+q_2)(1-c) y_2 - q_1 y_1] - \theta b q_1 - (\bar{r} - r). \tag{i}$$

Rearranging gives $\nabla\pi^f = q_1 \{[(1-c) y_2 - \theta b] + q_2 (1-c) y_2 - \theta b - q_1 y_1\}/2 - (\bar{r} - r)$. Substituting $q_2 = 1 - (1-c) q_1$ and $\bar{r} = r + \theta k$ results in

$$\nabla\pi^f = q_1 [(1-c) y_2 - \theta b] - \frac{q_1^2}{2} \left[y_1 + (1-c)^2 y_2\right] - \theta k. \tag{ii}$$

Use (20) to replace $[(1-c)\, y_2 - \theta b] = q_1 \left[y_1 + (1-c)^2 y_2\right]$ and get

$$\nabla \pi^f = \frac{q_1^2}{2} \left[y_1 + (1-c)^2 y_2\right] - \theta k, \tag{iii}$$

which is positive if (27) holds. If the condition is violated, firms borrow from investors, and financial intermediation breaks down. Relative to direct finance, bank credit boosts expected firm investment and output, since the optimal liquidation rate q_1 maximizes $\bar{y}$, and $\bar{y}'(0) > 0$ by (7). It then also boosts entry on account of $\pi^f \geq \pi^f|_{q_1=0}$. ■

Intuitively, the net benefit of entrepreneurs from potential expansion must outweigh the additional borrowing cost as bank credit is more equity-intensive due to regulation. Condition (27) holds if the cost of equity is small and banks actively reallocate credit from firms with low expected output to more successful and expanding firms. If $\theta k \to 0$, that is, if there is no agency cost of equity or banks are not subject to capital requirements, bank credit strictly dominates direct finance. In contrast, when reallocation is blocked in a 'rigid economy', where $\theta b \to (1-c)\, y_2$ and $q_1 \to 0$ in (20), borrowing from banks would be more expensive without offering any opportunity to expand.

Financial intermediation may therefore promise welfare gains compared to direct finance:

Proposition 5 ***(Gains from Intermediation)*** *Bank credit with expansion financing raises welfare relative to direct finance by boosting firm profits, entry investment and bankers' income if condition (27) holds.*

Proof. We compare welfare $V = \Pi - \Omega(n)$ under intermediation with $q_1 > 0$, $e = (k + bq_1)\, n$ and entry n, to welfare $V^d = \Pi^d - \Omega\left(n^d\right)$ under direct financing with $q_1 = 0$, $e = 0$ and entry $n^d < n$. Since there are no rents to bankers with direct finance, income in (12) is $\Pi^d = \pi^f\big|_{q_1=0} n^d + rI$. Investors always earn $\pi^i = rI$ in equilibrium, irrespective of the regime. Banking is welfare-improving as long as $V \geq V^d$ or, after substitution,

$$\pi^f n + (1-z)\, \pi^b + rI - \Omega(n) \geq \pi^f\big|_{q_1=0} n^d + rI - \Omega\left(n^d\right). \tag{i}$$

Expanding by $\pi^f n^d$, noting $\nabla \pi^f \equiv \pi^f - \pi^f\big|_{q_1=0}$ and rearranging gives

$$\nabla \pi^f \cdot n^d + (1-z)\,\pi^b + \pi^f \cdot \left(n - n^d\right) - \left[\Omega\left(n\right) - \Omega\left(n^d\right)\right] \geq 0, \tag{ii}$$

which finally yields

$$\nabla \pi^f \cdot n^d + \int_{n^d}^{n} \left[\pi^f - \omega\left(h\right)\right] dh + (1-z)\,\pi^b \geq 0. \tag{iii}$$

By Proposition 2, $\nabla \pi^f \geq 0$ if condition (27) holds, $\pi^f \geq \omega(h)$ for $h \leq n$, and $(1-z)\,\pi^b \geq 0$ as long as $\theta \geq 0$ and $p \leq 1$. ■

The first source of welfare gains in (iii) is the increase in profits of firms that already exist under market finance. The second term arises from induced entry $n - n^d$ due to financial intermediation and reflects the rents that accrue to entrepreneurs $h \in \left[n^d, n\right]$ with more talents than the marginal entrant n. The third source of welfare gains consists of the rents of bankers with a zero outside option which accrue only with bank financing but not with market finance. Intermediation offers welfare gains as long as agency costs in banking are not prohibitively high.

4.2 Firm-specific Loan Rates

After monitoring, banks observe how firms differ in their success probabilities. Instead of a uniform interest rate, they may offer a schedule of different rates on expansion loans depending on firm-specific risk, $i_2(q)$ for all $q \geq q_2$. Intuitively, firms with a high chance of success and repayment can borrow at a lower rate than those which are more likely to fail, $i_2'(q) \leq 0$. Interest on the first loan remains the same for all firms since no such information is available prior to monitoring. Interest earnings are thus $\bar{\imath} = \bar{q}_1 i_1 (1-q_1) + \int_{q_2}^{1} q i_2(q)\, dq$. The optimal cut-off q_1, which maximizes $\bar{\imath}$ subject to the regulatory constraint (4), depends on the uniform interest rate i_1 of the first loan and the specific rate $i_2(q_2)$ charged to the marginal expanding firm. Noting the multiplier θ of the regulatory constraint, optimality requires $-q_1 i_1 - q_2 i_2(q_2)\, q_2'(q_1) = \theta b$. Using the reallocation budget in (1) gives

$$q_1 = \frac{(1-c)\, i_2(q_2) - \theta b}{i_1 + (1-c)^2\, i_2(q_2)}. \tag{28}$$

To attract borrowers, banks offer contracts with a liquidation probability that maximizes expected firm profit. Solving $\pi^f = \max_{q_1} \bar{y}(q_1) - \bar{r} - \theta b q_1$ gives the very same optimal liquidation cut-off q_1 as in (20). By (1), the optimal cut-off q_2 for expansion financing is the same as well. Furthermore, expected borrowing costs of firms correspond to interest earnings $\bar{\imath}$, which equal refinancing costs of banks in zero profit equilibrium. Hence, expected firm profit equals $\pi^f = \bar{y}(q_1) - \bar{r} - \theta b q_1$, leading to the very same entry condition as in (22). The resulting allocation is identical to the baseline model.

At date 1, the bank specifies interest i_1 for initial credit and a schedule $i_2(q)$ for expansion credit. Those interest rates are set such that the bank's subsequent liquidation decision in (28) supports the optimal rates q_1 and $q_2 = 1 - (1-c) q_1$ given by (20),

$$i_2(q_2) = \frac{q_1 i_1 + \theta b}{(1-c) q_2}. \tag{29}$$

The key difference is in the firm-specific interest rate schedule, which nevertheless induces the same allocation. In the baseline model, a uniform loan rate i_2 implies that *expected* repayments of the very best firms with a high success rate, $q \to 1$, are much higher than the repayments of less successful firms. The credit portfolio thus involves cross-subsidization from more to less promising expansion projects. Once the type of a firm is known, competition for the best eliminates cross-subsidization until expected repayment is identical across all types, $i_2(q_2) q_2 = \bar{\imath}_2 = i_2(q) q$. The latter is determined by the marginal expansion project in (29). Intuitively, firm-specific loan rates treat the best firms better and offer less favorable terms to more marginal ones, $i_2(1) < i_2(q_2)$, compared to the baseline model with a uniform rate i_2 as stated in (A.3). To support an optimal liquidation and reallocation decision, banks must also satisfy condition (29) and therefore raise gross interest i_1 on initial loans, compared to the baseline case in (A.2). These loan rates are still low enough so that all continuation and expansion projects are privately profitable. Appendix C provides the proofs.

5 Conclusion

The 'Schumpeterian role' of banks is to reallocate credit from weak to strong firms and promote creative destruction. In our model, banks liquidate loans after observing poor prospects of success, and use liquidation proceeds to grant additional credit for expansion investment of firms with better prospects. The specific ability of banks to perform productivity-enhancing credit reallocation is the source of efficiency gains from financial intermediation compared to direct finance provided that the agency costs of equity or losses from loan liquidation are not excessive. We also identify distortions that hamper the 'Schumpeterian role' of banks. In the presence of agency costs and capital regulation, banks tend to reallocate too little credit and credit supply is too low, constraining entry and expansion investment. To mitigate distortions, policymakers may raise capital standards but reduce risk weights on reallocated expansion credit, which is only provided to more promising firms and is less risky. They may strengthen protection of outside shareholders that improves access to equity funding at lower cost, and improve bankruptcy procedures to boost recovery rates on liquidated credit. By shifting investment to better firms with higher chances of success, such reform stimulates credit reallocation and entrepreneurial investment, raises average firm-level output and aggregate capital productivity, and promises welfare gains.

The present paper emphasizes the interaction between credit reallocation and the capital structure of banks. The latter represents a key constraint on bank lending and is highly sensitive to policy interventions, in particular, to capital regulation. Our model is necessarily stylized and abstracts from several other factors that may also influence the reallocation process. In future research, one may thus relax some assumptions, for example, the inability of banks to refinance in-between, or add common frictions like monitoring imperfections or market power of relationship banks to evaluate how general the mechanism set out in this paper is. A quantitative analysis might be informative about the magnitude and the importance of the mechanism. The empirical evidence on 'Zombie lending', however, makes us confident that the main results also matter quantitatively.

Appendix

A. Loan Interest Rates in Constrained Equilibrium To solve for loan rates i_1 and i_2, we first calculate interest earnings $\bar{\imath} \equiv \bar{q}_1 i_1 (1-q_1) + \bar{q}_2 i_2 (1-q_2)$. Using (21) for i_2 and $\bar{q}_t (1-q_t) = (1-q_t^2)/2$ gives

$$\bar{\imath} = \left[1 - q_1^2 + \frac{(1-q_2^2)\, q_1}{(1-c)\, q_2}\right] \frac{i_1}{2} + \frac{1-q_2^2}{2} \frac{\theta b}{(1-c)\, q_2}. \tag{A.1}$$

By substituting $1-q_2^2 = (1-q_2)(1+q_2)$ and $1-q_2 = (1-c)\, q_1$ by (1), the expression in brackets equals $[1 + q_1^2/q_2]$. Use this in the break-even condition $\bar{\imath} = \bar{r} + \theta b q_1$ and solve for the loan rate i_1,

$$i_1 = \frac{2 q_2 \bar{r} - (1-q_2)\, \theta b q_1}{q_2 + q_1^2}. \tag{A.2}$$

Firms must be able to repay the loan, $y_1 \geq i_1$. Noting $q_2/(q_2+q_1^2) < 1$, Assumption 3, which is equivalent to $y_1 > 2\bar{r}$, indeed implies $y_1 > i_1$.

Combining (21) and (A.2) gives the interest rate on expansion loans,

$$i_2 = \frac{q_1 [2 q_2 \bar{r} - (1-q_2)\, \theta b q_1] + (q_2 + q_1^2)\, \theta b}{(q_2+q_1^2)(1-c)\, q_2} = \frac{2\bar{r} q_1 + (1+q_1^2)\, \theta b}{(1-c)(q_2+q_1^2)}. \tag{A.3}$$

Finally, we need to show that expansion investment is privately profitable, $y_2 > i_2$. Although a priori unclear, the above stated assumption $y_1 > 2\bar{r}$ indeed assures that the equilibrium loan rate is smaller than the project return. Substituting (A.3) into $y_2 > i_2$, multiplying by $(1-c)(q_2+q_2^2)$, and collecting terms gives

$$(1-c)\, y_2 q_2 - \theta b + [(1-c)\, y_2 - \theta b]\, q_1^2 > 2\bar{r} q_1. \tag{A.4}$$

Using (20) for q_2 and collecting the first and second terms gives

$$\frac{(1-c)\, y_2 - \theta b}{y_1 + (1-c)^2 y_2} y_1 + [(1-c)\, y_2 - \theta b]\, q_1^2 > 2\bar{r} q_1. \tag{A.5}$$

Using (20) again, the first and second terms are $q_1 y_1$ and $\left[y_1 + (1-c)^2 y_2\right] q_1^3$, leaving

$$y_1 + \left[y_1 + (1-c)^2 y_2\right] q_1^2 > 2\bar{r}. \tag{A.6}$$

Using the definition of θ and $\bar{r}$, Assumption 3 requires $y_1 > 2\bar{r}$ and thus implies (A.6). Given $y_1 > i_1$ and $y_2 > i_2$, firms earn a positive expected profit on both investments. Outstanding loans are fully repaid when investments are successful.

B. Comparative Statics We calculate results for all four shocks together. Since the equity premium θ only depends on the detection probability p, see (26), we subsequently omit this derivative and compute comparative static effects directly for θ.

Reallocation: Loan liquidation and reallocation are related by $1 - q_2 = (1-c)\, q_1$. Noting the effect on the buffer b, the optimal cut-off q_1 in (20) changes by

$$dq_1 = \sigma_k \cdot dk - \sigma_w \cdot dw - \sigma_\theta \cdot d\theta - \sigma_c \cdot dc, \tag{B.1}$$

where all coefficients are unambiguously positive,

$$\begin{aligned} \sigma_k &= \theta \frac{c + (1-w)(1-c)}{y_1 + (1-c)^2 y_2}, \quad \sigma_w = \theta \frac{(1-c)\, k}{y_1 + (1-c)^2 y_2}, \\ \sigma_\theta &= \frac{b}{y_1 + (1-c)^2 y_2}, \quad \sigma_c = \frac{[q_2 - (1-c)\, q_1]\, y_2 + \theta\,(1-wk)}{y_1 + (1-c)^2 y_2}. \end{aligned}$$

Although the effect of c is a priori ambiguous, the coefficient turns out positive since the cut-offs satisfy $q_2 > q_1$.

Expected Firm Output: Note $dq_2 = -(1-c) \cdot dq_1 + q_1 \cdot dc$ and get

$$d\bar{y} = \theta b \cdot dq_1 - q_2 y_2 q_1 \cdot dc. \tag{B.2}$$

The optimality condition (19) was used. Substituting (B.1) yields the final effect

$$d\bar{y} = \sigma_k \theta b \cdot dk - \sigma_w \theta b \cdot dw - \sigma_\theta \theta b \cdot d\theta - [q_2 y_2 q_1 + \sigma_c \theta b] \cdot dc. \tag{B.3}$$

Entry: Aggregate investment reflects reallocation and entry. By the free-entry condition, $d\pi^f = \omega'(n) \cdot dn$. Using the Envelope theorem on firm profits (19) and the change in the buffer coefficient (4), $db = -[1-(1-c)\, w] \cdot dk + (1-c)\, k \cdot dw + (1-kw) \cdot dc$, gives

$$\begin{aligned} \omega'(n) \cdot dn = & -\theta\,[1 - q_1 + w\,(1-c)\, q_1] \cdot dk - \theta k\,(1-c)\, q_1 \cdot dw \\ & - (k + b q_1) \cdot d\theta - [q_2 y_2 + (1-kw)\,\theta]\, q_1 \cdot dc. \end{aligned} \tag{B.4}$$

All shocks have well determined effects.

Capital Productivity: Productivity is total output per unit of capital, Y/I. Using the resource constraint $A = I - n$, total output in (11) is $Y = (\bar{y} - r)\, n + rI$. Since I is fixed, productivity changes along with $dY = n \cdot d\bar{y} + (\bar{y} - r) \cdot dn$. Assumption 1 implies $\bar{y} > r$.[14] In consequence, shifting investment from the residual to the entrepreneurial sector boosts capital productivity. Substituting (B.3-B.4) and defining the output elasticities of reallocation, $\mu \equiv \theta bn$, and of entry, $\eta \equiv (\bar{y} - r) / \omega'(n)$, gives

$$\begin{aligned} dY &= [\mu \cdot \sigma_k - \eta \cdot (1 - q_1 + (1 - c) w q_1) \theta] \cdot dk \\ &- [\mu \cdot \sigma_w + \eta \cdot (1 - c) q_1 k \theta] \cdot dw - [\mu \cdot \sigma_\theta + \eta \cdot (k + b q_1)] \cdot d\theta \\ &- [q_2 y_2 q_1 n + \mu \cdot \sigma_c + \eta \cdot (\theta (1 - wk) + q_2 y_2) q_1] \cdot dc. \end{aligned} \tag{B.5}$$

C. Firm-Specific Loan Rates Given cut-offs q_1 and q_2, we solve for firm-specific loan rates that eliminate cross-subsidization, $i_2(q) \equiv \bar{\imath}_2 / q$ where $\bar{\imath}_2$ is a uniform *expected* repayment on continuation projects. Interest earnings are $\bar{\imath} = \bar{q}_1 i_1 (1 - q_1) + \bar{\imath}_2 (1 - q_2)$. By (29), $\bar{\imath}_2$ must satisfy $\bar{\imath}_2 = (q_1 i_1 + \theta b) / (1 - c)$ to implement the optimal liquidation cut-off q_1. Substituting into the break-even condition gives

$$\bar{\imath} = \frac{(1 - q_1^2) i_1}{2} + \frac{(1 - q_2)(q_1 i_1 + \theta b)}{1 - c} = \bar{r} + \theta b q_1. \tag{C.1}$$

Using $1 - q_2 = (1 - c) q_1$ from (1) yields competitive loan rates,

$$i_1 = \frac{2\bar{r}}{1 + q_1^2}, \quad \bar{\imath}_2 = \frac{2\bar{r} q_1 + \theta b (1 + q_1^2)}{(1 - c)(1 + q_1^2)} = i_2(q)\, q. \tag{C.2}$$

The loan contract is feasible: $y_1 > i_1$ directly follows from Assumption 3, which implies $y_1 > 2\bar{r}$. It remains to show that the marginal firm earns a non-negative profit on expansion investment: $y_2 \geq i_2(q_2)$. By $i_2'(q) < 0$, the profits of all better projects $q > q_2$ are positive a fortiori. Substituting for $i_2(q_2) = \bar{\imath}_2 / q_2$ and rearranging gives

$$y_2 > i_2(q_2) \quad \Leftrightarrow \quad (1 - c) y_2 q_2 - \theta b > \frac{2\bar{r} q_1}{1 + q_1^2}. \tag{C.3}$$

Using $q_2 = 1 - (1 - c) q_1$ gives $(1 - c) y_2 q_2 - \theta b = [(1 - c) y_2 - \theta b] - (1 - c)^2 y_2 q_1 = y_1 q_1$, where the last equality uses the optimal cut-off in (20). The inequality in (C.3) reduces to $y_1 > 2\bar{r} / (1 + q_1^2)$ which is satisfied by assumption of $y_1 > 2\bar{r}$.

[14] Specifically, one can rewrite $\bar{y} = y_1/2 + \left[(1 - q_2^2) y_2 - q_1^2 y_1\right]/2$. Noting cut-offs in (20), the expression in square brackets is positive such that $\bar{y} > y_1/2$. Assumption 1 guarantees $y_1/2 > r$.

Finally, we prove the claims regarding the comparison of firm-specific loan rates to the baseline model. Upon substitution, one can immediately verify that the interest rate on the initial loan i_1 in (C.2) is higher than the baseline counterpart in (A.2). The inequality is equivalent to $2\bar{r}q_1 + (1 + q_1^2)\,\theta b > 0$, which is necessarily fulfilled. The marginal expansion credit of type q_2 pays a higher rate as in (C.2), compared to the uniform rate i_2 in (A.3), $i_2\,(q_2) > i_2$. Upon substitution, and after some rearrangements, the statement is seen to be equivalent to $q_2 < 1$ which is necessarily fulfilled.

D. Zombie Lending We first define a zero net present value (NPV) benchmark for date 1 and date 2 projects. Suppose that, in contrast to the baseline case, equity markets were perfect and banks were not subject to any funding restrictions at date 2. They could at any time get funding at rate r or invest unused funds in the alternative technology r. In this case, a bank would terminate at date 2 the initial project if liquidation yields a higher expected value $(1 - c)\,r$ than continuation, that is, if $NPV_1 = qy_1 - (1 - c)\,r < 0$. Negative NPV_1 projects with a low success rate should be liquidated,

$$q < \frac{(1 - c)\,r}{y_1} \equiv \tilde{q}_1, \quad q \geq \frac{r}{y_2} \equiv \tilde{q}_2. \tag{D.1}$$

The second inequality refers to an expansion project requiring 1 unit of capital, which should be financed as long as $NPV_2 = qy_2 - r$ is positive. We find that both $c > 0$ and $y_1 > y_2$ contribute to $\tilde{q}_2 > \tilde{q}_1$.

To establish the possibility of Zombie lending, we compare this benchmark to the cut-offs in market equilibrium, see (20). Banks cannot refinance at date 2 so that liquidation and expansion lending are related by the budget constraint $q_2 = 1 - (1 - c)\,q_1$. In addition, they face a higher cost of equity and are subject to capital regulation.

Compared to the benchmark (D.1), two distortions are possible: First, banks may engage in 'Zombie lending' by continuing credit lines to firms with negative NPV, $q_1 < \tilde{q}_1$. Second, they may provide insufficient credit for expansion financing if some projects are not undertaken even though their NPV is positive, $q_2 > \tilde{q}_2$. Substituting cut-offs gives

$$\begin{aligned} (i) &: \quad q_1 < \tilde{q}_1 \quad \Leftrightarrow \quad y_2 - r < (1-c)^2 \frac{r y_2}{y_1} + \frac{\theta b}{1-c} \equiv \bar{\varepsilon}, \\ (ii) &: \quad q_2 > \tilde{q}_2 \quad \Leftrightarrow \quad y_2 - r > (1-c)^2 \frac{r y_2}{y_1} - (1-c)\,\theta b \frac{y_2}{y_1} \equiv \underline{\varepsilon}. \end{aligned} \tag{D.2}$$

Zombie lending (case i) occurs if the expected return $y_2 - r$ on the second project of the best firm (type $q = 1$) is low. By Assumption 1, $y_1 > 2r > y_2 > r \geq 1$, the return $y_2 - r$ ranges between 0 and r, while the upper bound $\bar{\varepsilon}$ (r.h.s.) is positive and typically smaller than r (unless the term $\theta b/(1-c)$ is very large). Zombie lending is more likely if bank equity is very costly with a high premium θ, and if banks must raise large buffers b ex ante to comply with capital regulation ex post.

Insufficient expansion financing (case ii), in turn, occurs if the expansion project of the best firm is very profitable, the recovery rate is very low and diminishes the proceeds from liquidation; and the capital buffer is large and the agency costs are high.

Market equilibrium with $\theta b > 0$ necessarily implies $\bar{\varepsilon} > \underline{\varepsilon}$. To illustrate possible Zombie lending, we focus on the case $y_2 - r \in [\underline{\varepsilon}, \bar{\varepsilon}]$. This scenario is likely if the equity premium is high and banks must raise a large ex ante buffer such that $\underline{\varepsilon} \ll \bar{\varepsilon}$. Banks thus continue with some negative-NPV loans (see D.2.i) and do not finance all positive-NPV expansion projects (see D.2.ii). Given the costs of reallocation due to liquidation losses and equity buffers, expansion projects are not profitable enough to induce liquidation of all initial projects with negative NPV. Underinvestment at the expansion stage occurs because banks cannot generate the required funds. Credit is locked up in inefficient projects instead of making them available for expansion financing with positive-NPV projects. Therefore, Zombie lending necessarily blocks expansion of more successful firms.

E. Unconstrained Market Equilibrium The first-best allocation is decentralized as a competitive market equilibrium without incentive and regulatory capital constraints.

Reallocation: Once it observes the success probability at date 2, the bank liquidates loans which are unlikely to be repaid, and uses liquidation proceeds to scale up loans of firms with a higher success probability. Given interest rates i_1 and i_2, the bank chooses the liquidation cut-off q_1 to maximize expected interest earnings,

$$\bar{\imath} = \max_{q_1} \bar{q}_1 i_1 (1 - q_1) + \bar{q}_2 i_2 (1 - q_2). \tag{E.1}$$

Optimality requires $-q_1 i_1 - q_2 i_2 q_2' (q_1) = 0$. Using $q_1' (q) = -(1 - c)$,

$$q_1 = \frac{(1-c)\, i_2}{i_1 + (1-c)^2 i_2}, \quad q_2 = 1 - (1-c)\, q_1 = \frac{i_1}{i_1 + (1-c)^2 i_2}. \tag{E.2}$$

Capital Structure and Credit Contract: At date 1, banks raise equity and set loan rates to compete for business. Bank profits are $\pi^b = \bar{\imath} n - rd$. Since the banker (insider) cannot divert any resources, investors receive the entire profit as dividends, $z = 1$, giving a surplus of $S^o = \pi^b - re = (\bar{\imath} - r)\, n \geq 0$. Since it has no bearing on profit, the capital structure is indeterminate (Modigliani-Miller). The linearity in n implies that competitive banks provide loans until they hit break even, $\bar{\imath} = r$.

To compete for loans, each bank sets the structure of loan rates i_1 and i_2 to induce a liquidation rate in (E.2) that maximizes expected firm profit subject to break-even of bank owners, $\pi^f = \bar{y}(q_1) - \bar{\imath} = \bar{y}(q_1) - r$. The optimal cut-offs q_1 and q_2 are

$$\bar{y}'(q_1) = 0 \quad \Rightarrow \quad q_1 = \frac{(1-c)\, y_2}{y_1 + (1-c)^2 y_2} = q_1^*, \quad q_2 = \frac{y_1}{y_1 + (1-c)^2 y_2} = q_2^*. \tag{E.3}$$

Comparing to (14), the optimal cut-offs are seen to be first best.

The bank must set loan rates i_1 and i_2 to induce a liquidation decision at date 2 as in (E.2) which supports the optimal cut-offs in (E.3). Given q_1 and q_2, the loan rates must be set to satisfy the ratio

$$\frac{i_2}{i_1} = \frac{q_1}{(1-c)\, q_2}. \tag{E.4}$$

Given this ratio, the bank proportionately scales down loan rates to shift the surplus towards entrepreneurs until it hits break-even, $r = \bar{\imath} = \bar{q}_1 i_1 (1 - q_1) + \bar{q}_2 i_2 (1 - q_2)$. Replacing i_2 by (E.4) and using $1 - q_2 = (1-c)\, q_1$ gives $r q_2 = [(1 - q_1)\, \bar{q}_1 q_2 + \bar{q}_2 q_1^2] \cdot i_1$. Next, substitute $\bar{q}_t (1 - q_t) = (1 - q_t^2)/2$ and rearrange to get the loan rate i_1

$$i_1 = \frac{2 q_2}{q_2 + q_1^2} \cdot r, \quad i_2 = \frac{2 q_1}{(1-c)(q_2 + q_1^2)} \cdot r. \tag{E.5}$$

The rate i_2 follows by substituting i_1 into (E.4).

Since $y_1 > 2r$ by Assumption 1 and interest on the initial loan satisfies $2r > i_1$ by (E.5), firms earn a strictly positive profit $y_1 - i_1$ on the first investment.

Finally, we need to show $y_2 \geq i_2$. Replacing i_2 by (E.5) gives $y_2 (1 - c) (q_2/q_1 + q_1) \geq 2r$. Use (E.3) to substitute for q_2/q_1 and get $y_1 - 2r + (1 - c) q_1 y_2 \geq 0$. Since $y_1 > 2r$ by Assumption 1, this inequality is fulfilled. This establishes $y_2 - i_2 \geq 0$, that is, firms make positive profits on expansion investment.

Entry: Entrepreneurs start firms as long as $v^e (h) = \pi^f - \omega (h) \geq 0$. With competitive banks earning zero profits in equilibrium, $\bar{\imath} = r$, expected firm profit equals $\pi^f = \bar{y} (q_1) - r$. The free-entry condition pins down the marginal entrant

$$\omega (n) = \bar{y} (q_1) - r. \tag{E.6}$$

The free-entry condition satisfies the condition for a first-best allocation as in (14), and so does the equilibrium rate of liquidation in (E.3). The use of equity capital in banking is indeterminate as in the first best. The unconstrained market equilibrium thus decentralizes the efficient allocation noted in Section 3.1.

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