

Schumpeterian Banks: Credit Reallocation and Capital Requirements*

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Abstract

Capital reallocation from unprofitable to profitable firms is a key source of productivity gain in an innovative economy. We present a model of credit reallocation and focus on the role of banks: Weakly capitalized banks hesitate to write off non-performing loans to avoid a violation of regulatory requirements or even insolvency. Such behavior blocks credit reallocation to expanding industries and results in a distorted investment process and low aggregate productivity. Reducing the cost of bank equity, tightening capital requirements, and improving insolvency laws relaxes constraints and mitigates distortions.

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1 Introduction

One of the main economic functions of the financial sector is to efficiently allocate capital by channeling funds towards those firms that can use them most productively. Banks and other financial intermediaries perform functions such as credit risk analysis, monitoring of borrowers, and liquidation of loans with poor prospects. The latter may lead to the closure of firms without a viable business model. At the same time, banks are able to recover capital which would otherwise be blocked, and to reallocate the released funds to new ventures. 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. The current efforts to strengthen banks' balance sheets and capital structure need to be seen in this light 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.'

Weakly capitalized banks, in contrast, tend to delay restructuring of non-performing loans since write-offs could violate regulatory constraints or even lead to insolvency. Banks instead continue lending to quasi-insolvent borrowers hoping that they will recover and eventually pay back. Such behavior distorts the capital allocation, slows down the expansion of productive firms and leads to congested product markets. The Japanese crisis in the 1990s is a prominent example. Many Euro area banks currently face the need to restructure their loan portfolios as non-performing assets roughly doubled between 2008 and 2014 and reached an amount worth more than 9 percent of GDP (Shekhar et al., 2015). These increases have been particularly strong in southern Europe, for example, in Greece, Italy, Portugal and Spain. According to the IMF (2017), non-performing loans were 36%, 18%, 12%, and 9% of total loans respectively in 2016. Economists and policy makers are increasingly concerned about a scenario similar to Japan's 'lost decade' with weak banks that curtail new lending and delay the recovery. Mario Draghi warned: 'Put

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

bluntly, this would create “zombie” banks that do not lend, and the longer this persists, the longer credit conditions will interfere with the process of creative destruction described by Schumpeter. The “churn” process between firms entering and exiting the market that is a crucial driver of productivity would be disrupted.’

In the present paper, we investigate how banks contribute to creative destruction by reallocating credit. The model emphasizes the role of capital structure of banks in financing firms which operate in expanding and downsizing parts of the economy. After investment projects are initiated, banks observe the success probabilities which are often quite low in the downsizing sector, indicating poor prospects. The bank decides whether to continue lending or not. If it liquidates a loan, it can reallocate the released funds to more promising ventures but must absorb the losses from the write-off which impairs equity. At the same time, investors are hesitant and recapitalization is difficult after a bank had to write off many non-performing loans. To satisfy capital requirements, banks must thus raise a voluntary capital buffer a priori. As long as equity is expensive, they trade off the benefit of more aggressive credit reallocation against the extra cost of the capital buffer. Thus, aggregate investment is distorted: Banks liquidate too few non-performing loans and engage in ‘Zombie’ lending to non-viable firms which should be closed down. Such behavior tends to block capital reallocation and also distorts startup investment. As a result, aggregate productivity is impaired. These problems are more severe whenever equity requires a high premium, capital requirements are low, and loan liquidation is costly.

The stylized example in Figure 1 illustrates the main mechanism: The left panel shows the balance sheet of a bank that granted loans of 50 each to firms in two sectors of the economy, x and y , and is funded by deposits d and equity e . Monitoring reveals that 20% of loans to the downsizing y -sector are unlikely to be repaid and should be liquidated. Liquidation allows the bank to recover 75% of the principal’s value and to reallocate the released funds to the expanding x -sector by granting additional loans. The consequences are shown in the central panel: Liquidating the non-performing loans worth 10 thus yields

proceeds of 7.5, which are reallocated leaving an amount of 57.5 and 40 of x - and y -loans respectively. The liquidation loss of 2.5 immediately impairs bank equity. This affects regulatory requirements: Suppose the capital requirement is 8%, equity after reallocation needs to be at least $8\% \times 97.5 = 7.8$. Costly liquidation affects this constraint in two ways: It lowers the required capital by 0.2 because of the decrease in total assets and, more importantly, directly impairs equity by 2.5. As long as banks face difficulties to recapitalize after substantial write-offs, they need to raise more equity upfront: $e \geq 2.5 + 7.8 = 10.3$. Therefore, banks hold a buffer of at least 2.3 in excess of capital charges to satisfy the regulatory requirements after reallocation. In case the buffer is too low, for example, $e' = 9$ as shown in the right panel, capital requirements constrain credit reallocation. Banks can liquidate a volume of at most 4.35 instead of 10. Writing off a quarter of 1.09, equity after reallocation is 7.91, which exactly corresponds to an 8% capital ratio. Banks grant fewer new loans to the expanding x -sector (3.26 instead of 7.5) but continue lending to some non-viable firms in the y -sector (yellow-shaded area).

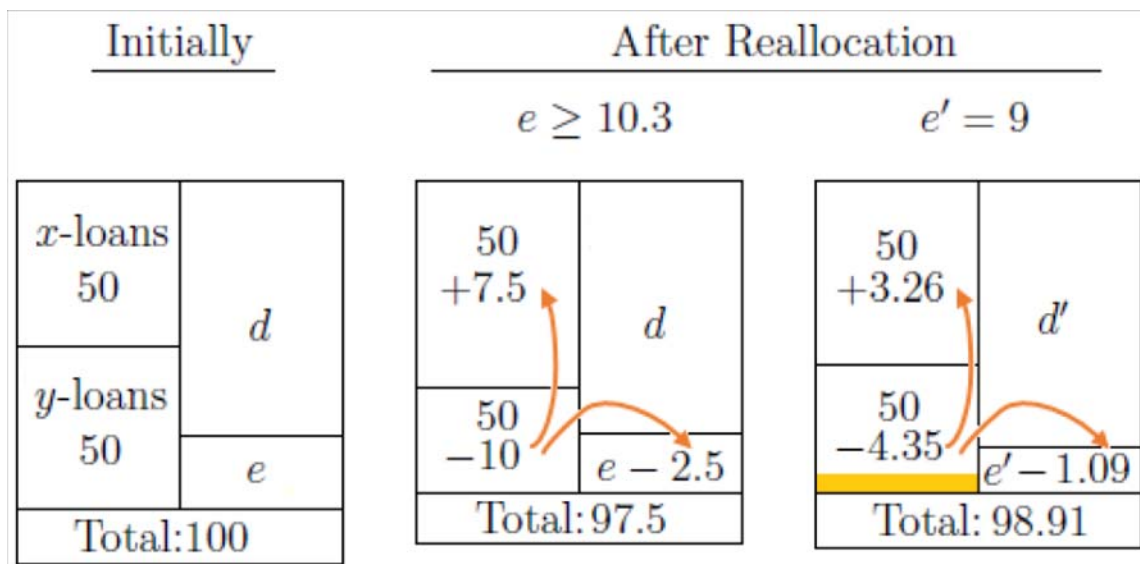


Figure 1: Credit Reallocation and Bank Equity

The paper builds on two established empirical facts in the finance and growth literature. First, capital and labor allocation is crucial for growth and productivity. Bartelsman, Haltiwanger and Scarpetta (2013) estimate that labor productivity in the U.S. manufacturing sector is 50 percent higher than it would be in case labor was randomly

allocated across firms. The importance of reallocation for productivity growth is also documented at the industry level, for example, by Olley and Pakes (1996) and Foster, Haltiwanger and Krizan (2006). These results are broadly consistent with M&A research which finds that the productivity of an asset tends to increase after its sale and subsequent acquisition (e.g., Maksimovic and Phillips, 2001; Schoar, 2002). A large amount of financial assets is reallocated each year. According to Eisfeldt and Rampini (2006), capital reallocation measured by sales and acquisitions of property, plants and equipment accounts for roughly one quarter of investment. Dell’Ariccia and Garibaldi (2005) study the gross credit flows resulting from simultaneous credit expansion and contraction of banks in the United States. They show that sizeable flows coexist at any phase during the business cycle. The volatility of these flows is considerably larger than that of GDP. Herrera, Kolar and Minetti (2011) examine the reallocation of credit across firms which is quantitatively important, highly volatile and slightly procyclical. Credit is mainly reallocated across firms of similar size, industry and location.

Second, there is substantial empirical evidence that financial development improves the efficiency of capital allocation and fosters economic growth (e.g., King and Levine, 1993a, 1993b; Rajan and Zingales, 1998; Beck, Levine and Loyaza, 2000; Beck and Levine, 2004; Fisman and Love, 2007). Typically, the effect of size-related measures like, for example, private credit or stock market capitalization on income, growth and productivity is estimated in reduced form using cross-country data. Given the finding that productivity crucially depends on capital and labor allocation, the ‘Schumpeterian role’ of finance provides one explanation for the observed positive effect. In a seminal contribution, Wurgler (2000) shows that countries with more developed financial markets as measured by size and institutional characteristics are better able to increase investment in growing and to withdraw funds from declining industries. More precisely, financial development increases the elasticity of investment to value added in an industry. If value added increases by one percent, investment rises by only 0.22 percent in a country with a weakly (Indonesia) and by 0.99 percent in a country with a highly developed financial sector (Germany). An alternative approach which exploits policy changes yields comparable insights. The

efficiency of investment and capital allocation tends to increase after liberalization of the banking sector, for example, due to branch deregulation in U.S. states between the 1970s and 1990s (Jayaratne and Strahan, 1996; Acharya, Imbs, and Surgess, 2011) or due to banking reforms in France in the mid 1980s which significantly reduced government interventions in banks' lending decisions (Bertrand, Schoar and Thesmar, 2007).

A weak financial sector may turn into an obstacle for reallocation and growth. The 'lost decade' in Japan during the 1990s serves as a prominent example. The massive decline in asset prices impaired collateral values. Troubled banks were reluctant to restructure non-performing loans to avoid write-offs that would have weakened their already low capitalization. Instead, they continued lending to de facto insolvent borrowers, so-called forbearance or 'Zombie' lending. Peek and Rosengren (2005) provide evidence that firms under financial stress were more likely to receive additional credit. This effect was particularly strong for banks with a capital ratio close to the regulatory minimum. 'Zombie' lending creates various distortions as shown by Caballero, Hoshi and Kashyap (2008). Industries with many 'Zombie' firms exhibit reduced job creation and destruction and lower TFP growth. Congestion in product markets reduces the profits of productive firms and significantly decreases their employment growth and investment. The authors calculate a cumulative loss of investment over a ten-year period equal to 17% of capital, corresponding to an investment volume of one year.

Since the recent crisis, growing concerns about a similar scenario in parts of the Eurozone have been articulated. Acharya et al. (2016) examine the ECB's Outright Monetary Transactions (OMT) program, which indirectly recapitalized (primarily southern) European banks by boosting the value of their sovereign bonds. Banks that regained some lending capacity due to OMT 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, increased loans to corporate borrowers while reducing 'Zombie' loans from 9% to 6%. Similar to Japan, they estimate negative effects of a large share of 'Zombie' firms in an industry on investment and employment growth of

healthy firms. Schivardi, Sette and Tabellini (2017) focus on credit misallocation during the financial crisis in Italy. Weakly capitalized banks were less likely to cut credit to ‘Zombie’ firms: Credit growth to such firms by banks with a below median capital ratio is 25% stronger compared to the average. Importantly, such banks hesitate to classify ‘Zombie’ loans as ‘substandard’ or ‘bad’, which would force them to set aside loss provisions and affect equity. This finding is consistent with evidence of Huizinga and Laeven (2012) that weak banks reported significantly lower provisions during the U.S. mortgage crisis and exploited their discretion to boost book values and avoid write-offs.

On the theoretical side, the finance-growth literature usually relies on reduced-form models of the financial sector. King and Levine (1993b) develop an endogenous growth model where financial intermediaries evaluate entrepreneurs and finance their innovative activities. They show that financial sector distortions reduce growth. Almeida and Wolfenzon (2005) study the effect of external finance on the efficiency of the capital allocation. External financing needs of firms ensure that more intermediate or unprofitable projects are liquidated. The larger supply reduces the cost of capital, which allows financially constrained firms with productive investments to attract more funds. Eisfeldt and Rampini (2006) analyze the cyclical properties of reallocation. Illiquidity modeled as adjustment costs can explain the procyclicality of reallocation which contrasts with its apparently countercyclical benefits. Hence, this friction hampers reallocation exactly when it promises the largest benefits. Caballero et al. (2008) develop an entry and exit model. Limiting firm destruction by ‘Zombie lending’ depresses productivity by preserving inefficient firms and implies a stronger adjustment to shocks at the firm creation margin.

Models in corporate finance highlight the role of internal capital markets. Stein (1997) shows how an internal capital market improves the efficiency of capital allocation in the presence of financial constraints. Headquarters allocate scarce capital more efficiently by engaging in ‘winner-picking’. Funds are channeled to the most promising projects and withdrawn from less promising ones. As a result, actual investment in one division is sensitive to the investment prospects of otherwise unrelated divisions of the same firm.

Giroud and Mueller (2015) find empirical support for winner-picking. They document investment spillovers in the presence of financial constraints: If one plant receives an investment opportunity, the firm withdraws capital and labor from other, less productive plants to mobilize funds. This leads to an increase in firm-wide productivity. However, there is no evidence for intra-firm reallocation in financially unconstrained conglomerates.

In the theoretical banking literature, capital reallocation connects to the analysis of loan liquidation and forbearance. Such models emphasize risk shifting that emerges due to limited liability: Weakly capitalized banks have an incentive to continue lending to insolvent borrowers, hide bad loans and gamble for resurrection. A certain capital ratio is necessary to avoid this behavior. Examples are Bruche and Llobet (2013), who suggest a voluntary scheme to prevent ‘Zombie’ lending when loan quality is private information of banks, and Homar and van Wijnbergen (2017), who study how recapitalizing banks with an unexpectedly large number of non-performing loans can prevent forbearance. Eventually, the topic shares some similarities with credit decisions of banks. Inderst and Mueller (2008) analyze a bank’s decision whether to finance a risky project based on a noisy signal. They characterize the optimal capital structure of banks, which ensures that the credit decision is first-best.

So far, the focus of the theoretical finance and growth literature has mainly been on firms and entrepreneurs and not on banks that are, if at all, modeled in reduced form. In banking theory, some recent papers analyze forbearance. By emphasizing risk-shifting incentives at the bank level, such an approach captures only parts of the reallocation process, however. The main contribution of this paper is that it explicitly analyzes the determinants of credit reallocation by banks and, by modeling the economy-wide equilibrium, the consequences for startup investment and aggregate productivity. Our theoretical framework highlights that reallocation is key for the expansion of innovative sectors, which is consistent with evidence that it accounts for roughly one quarter of investment. The paper specifically explains how the central mechanism of credit reallocation depends on capital standards, the cost of bank equity, insolvency laws or pull factors such as in-

vestment opportunities in expanding sectors. This helps clarifying the role of financial development and of the institutional environment for productivity. We focus on the role of banks' capital structure, which is at the core of current regulatory reforms. Our analysis shows that banks raise too small capital buffers which gives rise to 'Zombie' lending, shifts the investment process in the innovative sector from reallocation towards startup activity with high costs, and lowers aggregate productivity. In particular, the results support policies that aim to lower the cost of bank equity (e.g., tax reforms, governance and investor protection) and point to the role of capital standards in supporting reallocation.

Section 2 sets out the model. Section 3 analyzes equilibrium, explores efficiency properties and comparative static effects, and derives testable predictions. Section 4 concludes.

2 The Model

All agents are risk-neutral. Endowments are entrepreneurial labor of mass one and capital owned by investors. Each firm is run by an entrepreneur and needs one unit of capital. Since they have no own funds, investment is financed with bank credit. Entrepreneurs can either start an x -firm with a high-risk, high-return project (a more radical innovation) or a y -firm with a more opaque and uncertain project. Both firms thus produce the same *numeraire* good but with a different technology.

Banks intermediate investor funds and transform them into business credit. In an interim period, monitoring reveals a performance signal for y -sector firms, and banks liquidate non-performing loans and reallocate funds to firms in the x -sector. The economy thus consists of a downsizing y -sector where part of the firms are liquidated when receiving an unfavorable shock, and an expanding x -sector. Reallocation of capital from the declining industry finances new x -firms in addition to original startups.

Firms: In the innovative x -sector, a firm produces x units of output with probability p , and zero with probability $1 - p$. Capital fully depreciates and cannot be used elsewhere.

The firm pays gross interest i_x and expected firm profit amounts to

$$\pi_x = p(x - i_x). \quad (1)$$

Firms in the downsizing y -sector receive a loan of size one at a gross interest i_y . They produce y if they succeed and zero if they fail. Projects are more opaque and uncertain in that they are successful with a heterogeneous probability $q' \in [0, 1]$. In the beginning, only the distribution of success probabilities is known. Given a uniform distribution, the average firm succeeds with probability $E[q'] = \int_0^1 q' dq' = 1/2$. In the interim period, the bank monitors and learns the true success probability q' of each firm.² It liquidates unprofitable firms with little chances for success $q' < q$ where q denotes the pivotal type chosen by the bank. A share $\int_0^q dq' = q$ of firms is closed down and the remaining part $1 - q$ continues. After continuation, a firm finally succeeds with probability q' , produces output y and generates profit $y - i_y$, or fails and produces nothing with probability $1 - q'$. Ex ante, the unconditional success probability of an entrant is

$$\hat{q} = \int_q^1 q' dq' = \frac{1 - q^2}{2}, \quad \frac{d\hat{q}}{dq} = -q. \quad (2)$$

The success probability conditional on continuation (i.e., on not being liquidated) is

$$\bar{q} = E[q' | q' \geq q] = \frac{\int_q^1 q' dq'}{1 - q} = \frac{1 + q}{2}, \quad \frac{d\bar{q}}{dq} = \frac{1}{2}. \quad (3)$$

With a uniform distribution, the two probabilities are related by $\hat{q} = (1 - q)\bar{q}$. Conditional on continuation, expected firm profit is

$$\pi_y = \bar{q}(y - i_y). \quad (4)$$

Banks raise deposits d and equity e from investors, paying returns r and $\rho > r$. They lend to firms in both sectors. The loan volume is n_x and n_y , respectively. Whenever monitoring reveals a low success probability, they liquidate non-performing loans of y -firms, collect liquidation values and lend the proceeds to new x -firms. Banks charge

²Appendix B shows that this simple formulation is robust to imperfections in loan assessment.

interest rates i_y on loans to the y -sector as well as i_x and i'_x on initial and reallocated loans in the x -sector. Expected profits are

$$\pi_b = pi_x n_x + \pi_{by} n_y - rd - \rho e, \quad \pi_{by} \equiv \bar{q} i_y (1 - q) + pi'_x (1 - c) q, \quad d = n_x + n_y - e, \quad (5)$$

where π_{by} is the expected value of a y -loan: With probability $1 - q$, the bank continues lending and earns expected interest income $\bar{q} i_y$. With probability q it liquidates the loan. In this case, the bank extracts only $1 - c$ of the loan and incurs a loss c , which reflects the liquidation cost and depends on institutional factors like, for example, the quality of insolvency laws or investor protection, as well as the bank's expertise. Hence, the proceeds $1 - c$ become available for new loans with expected interest income pi'_x . Since loan size is one, the mass of additional x -firms that get funded is $(1 - c) q n_y$. Aggregate investment after reallocation is

$$n'_x = n_x + (1 - c) q n_y, \quad n'_y = n_y - q n_y. \quad (6)$$

Entrepreneurs operate firms. They can enter either the innovative or the downsizing sector. When starting an x -firm, expected profit is π_x . When starting a y -firm, expected profit is affected by the bank's liquidation decision after initial investment. We assume that entrepreneurs who failed in the y -sector may get a second chance for a fresh start in the x -sector.³ An entrepreneur entering the y -sector thus faces three possible events: (i) continue with probability $1 - q$ if the signal is good enough; (ii) get liquidated and become a 'serial' entrepreneur with a new x -firm with probability $(1 - c) q$. The expected profit $\pi'_x = p(x - i'_x)$ differs from the profit of directly entering the x -sector due to a different loan rate; and (iii) get liquidated and fail to get a second chance with probability cq . Liquidated firms are rationed by the limited amount of released funds. Figure 2 illustrates. Starting a y -firm thus yields an expected profit of

$$\bar{\pi}_y = \pi_y \cdot (1 - q) + \pi'_x \cdot (1 - c) q. \quad (7)$$

³Fresh-start policy is indeed an important feature of insolvency laws, see White (2011). Gompers et al. (2010) find substantial evidence on serial entrepreneurship.

We picture an economy where more radical innovations offer larger profit opportunities, $\pi_x > \bar{\pi}_y$. This is ensured by the assumption⁴ $2px - y - [px(1-c)]^2/y > 0$.

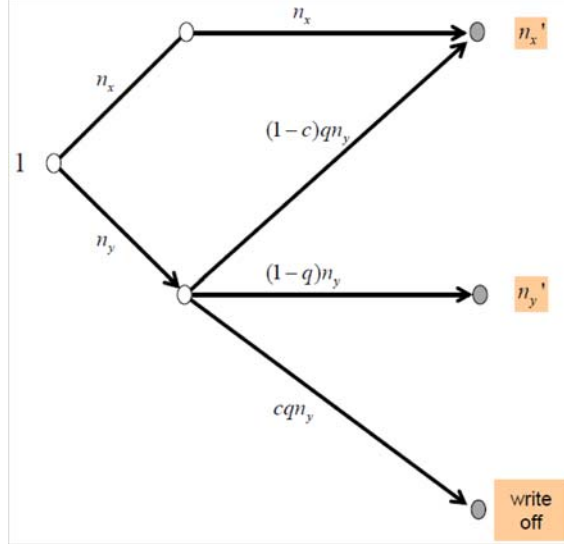


Figure 2: Credit Reallocation

In the beginning, entrepreneurs need to exert effort, for instance, to do some initial R&D and to develop a business plan. They may opt for a more radical innovation strategy by starting an x -firm or pursue a more opaque and uncertain y -firm with many possible outcomes (in terms of the success probability q'). Importantly, entering the innovative sector requires either high talent or experience acquired from serial entrepreneurship. We assume that talent $h \in [0, 1]$ is heterogeneous and uniformly distributed among entrepreneurs. High talent means low entry cost in terms of R&D effort, $\omega(h)$, which is increasing in type h , $\omega'(h) > 0$. Imposing Inada conditions $\lim_{h \rightarrow 0} \omega(h) = 0$ and $\lim_{h \rightarrow 1} \omega(h) = \infty$ assures an interior solution for the choice of innovation strategy. If n_x is the pivotal type opting for an x -project, the of x -entrants is

$$n_x = \int_0^{n_x} dh, \quad \Omega(n_x) = \int_0^{n_x} \omega(h) dh. \quad (8)$$

The second term Ω reflects aggregate entry costs in terms of an R&D effort which rises with the cost of the marginal entrepreneur, $\Omega'(n_x) = \omega(n_x)$.

⁴Following Proof 1, $\pi_x > \bar{\pi}_y \Leftrightarrow px > \bar{y}$. Substitute \bar{y} and use q in (17).

An entrepreneur's welfare is expected income minus effort cost. Normalizing the effort of a y -project to zero, an effort cost is incurred only for an x -project developed without prior experience. Such a project may also be created by serial entrepreneurs in which case initial effort is replaced by experience. Hence, an entrepreneur of type h opts for an x -project if $\pi_x - \omega(h) \geq \bar{\pi}_y$, and otherwise chooses a less ambitious strategy with a y -firm. Clearly, only the types with more entrepreneurial talent start right from the beginning with an x -project. The occupational choice condition splits entrepreneurs by

$$\pi_x - \omega(n_x) = \bar{\pi}_y. \quad (9)$$

Investors are endowed with capital I which they invest in deposits, bank equity and an alternative investment opportunity A yielding a return r . Investor profits are

$$\pi_i = \rho e + rd + rA, \quad e + d + A = I, \quad \rho = \theta + r. \quad (10)$$

Assets are perfect substitutes up to an equity premium θ . In consequence, the supply of deposits and equity is perfectly elastic at rates r and ρ . The equity premium compensates for investor effort on oversight and management, giving welfare $\pi_i - \theta e$.

Equilibrium: Initial investment, $n_x + n_y = 1$, results from sectoral choice and bank lending. Each x -firm survives with probability p and produces expected output px . Downsizing of the y -sector and credit reallocation of released funds further expands the x -sector. Using (6), aggregate output $X = pxn'_x$ and $Y = \bar{q}yn'_y$ after reallocation is equal to expected output prior to reallocation,

$$X + Y = pxn_x + \bar{y}(q)n_y, \quad \bar{y}(q) \equiv px(1-c)q + \bar{q}y(1-q). \quad (11)$$

Total income equals

$$\Pi = \pi_x n_x + \bar{\pi}_y n_y + \pi_b + \pi_i, \quad (12)$$

and is spent on the numeraire goods. Substituting profits and using (11) yields

$$\Pi = X + Y + rA. \quad (13)$$

Aggregate demand is equal to total income Π and matches supply of x - and y -sector firms plus output rA of the alternative technology in (10). Alternative investment is residually determined, $A = I - e - d = I - 1$, and reflects capital market clearing.

3 Equilibrium Analysis

This section first establishes an unconstrained first-best allocation. We then introduce capital requirements, compute the equilibrium and identify the distortions. Eventually, testable predictions and policy options are derived from a comparative statics analysis.

3.1 Unconstrained Reallocation

The timing is: (i) credit contracts and initial lending, (ii) monitoring and liquidation. Solution is by backward induction. We first solve for optimal liquidation and credit reallocation, conditional on previous interest rates. Then we proceed with initial lending decisions which anticipate subsequent results.

Credit Reallocation: At the reallocation stage, the bank observes the success probability q' of any y -firm and decides whether to continue or terminate the loan. The liquidation cut-off q maximizes expected earnings on all loans initially made to y -firms

$$\pi_{by} = \max_q \int_q^1 q' i_y dq' + \int_0^q p i'_x (1 - c) dq'. \quad (14)$$

The first term equals the expected interest earnings of firms with a sufficiently good signal. The credit is continued since they are likely to repay the loan. The second term relates to firms with a low success probability which are unlikely to repay. They are liquidated, and the bank writes off a part c of the outstanding credit. It can extract a liquidation value of $1 - c$ and lend these proceeds to new x -firms giving expected earnings $p i'_x$. The bank's optimal cut-off satisfies

$$q i_y = p i'_x (1 - c) \quad \Rightarrow \quad q = \frac{p i'_x (1 - c)}{i_y}. \quad (15)$$

The marginal firm is chosen such that the bank is indifferent between continuation giving expected earnings of qi_y and liquidation giving $pi'_x(1-c)$.

Lending and Capital Structure: Initially, the bank provides unit loans to x - and y -firms. It is a price taker on loan and deposit markets. Collecting terms in (5), expected profits are seen to be linear in loans and decreasing in equity:

$$\pi_b = [pi'_x - r] \cdot n_x + [\pi_{by} - r] \cdot n_y - \theta e, \quad \pi_{by} \equiv \bar{q}i_y(1-q) + pi'_x(1-c)q. \quad (16)$$

Since equity has no advantage but requires a premium θ , a bank chooses $e = 0$.

In competing for loans, banks cut loan rates until break-even (Bertrand competition). More precisely, competitive banks offer credit contracts - they set interest rates - to attract firms. To successfully compete, the contract is designed to maximize expected firm profits π_x and $\bar{\pi}_y$ subject to a break-even constraint. A bank could otherwise steal business from other banks by offering a contract that promises higher profits. In consequence, competitive banks make zero profits on both types of loans and are willing to supply any quantity. The sectoral allocation n_x and n_y is pinned down by the demand side.

Expected repayment of an x -loan just covers the refinancing cost $i_x = r/p$. In case of a y -startup, the bank offers two interest rates: i_y if the firm continues and i'_x if credit is reallocated and the entrepreneur starts new in the x -sector. Again, loan rates maximize expected profit $\bar{\pi}_y$ subject to the constraint that total earnings (either from continuation or liquidation and new lending) must match at least the bank's refinancing cost, $\pi_{by} \geq r$. In competing for loans, the bank first maximizes the joint surplus $S \equiv \pi_{by} + \bar{\pi}_y - r = \bar{y}(q) - r$, by choosing the cut-off q . In a second step, it scales down loan rates until break-even. Maximizing the joint surplus yields

$$\frac{d\bar{y}(q)}{dq} = px(1-c) - qy = 0 \quad \Rightarrow \quad q = \frac{px(1-c)}{y}. \quad (17)$$

The loan rates i'_x and i_y jointly affect the bank's liquidation decision as in (15). To support optimal liquidation, interest rates must be set to satisfy the ratio

$$\frac{pi'_x(1-c)}{i_y} = \frac{px(1-c)}{y} \quad \Leftrightarrow \quad i'_x = \frac{x}{y} \cdot i_y. \quad (18)$$

In a second step, the bank proportionately scales down loan rates to shift the surplus towards entrepreneurs until it hits break-even. Using (15) in the break-even constraint $\pi_{by} = r$ and solving for i_y in terms of the optimal q gives $\bar{q}i_y(1-q) + i_yq^2 = r$ which is rearranged to yield

$$i_y = \frac{2}{1+q^2} \cdot r, \quad i'_x = \frac{x}{y} \cdot i_y = \frac{2}{1+q^2} \frac{x}{y} \cdot r, \quad (19)$$

where q is the optimal cut-off in (17). The loan rates exceed the deposit rate and satisfy $i'_x > i_y > r$. The first inequality is due to $x > y$ and the second one results from $q < 1$ which requires an assumption on returns and liquidation cost, $px(1-c) < y$. Finally, with competition among banks, $\pi_{by} = r$, firms are able to extract the entire joint surplus $\bar{\pi}_y = \bar{y}(q) - r$ which depends on the optimal liquidation cut-off q .

Industry structure: Entrepreneurs start firms with a more or less innovative technology whichever is more valuable. When pursuing a radical innovation, expected profit is π_x . When entering the y -sector, the entrepreneur could succeed, fail and get a second chance, or fail completely. Relative expected profits $\pi_x > \bar{\pi}_y$ do not change when entry shifts from one to the other sector. Industry structure is determined by sectoral choice and driven by heterogeneous entry costs, see (9), yielding equilibrium entry n_x .

Welfare: A type h -entrepreneur expects welfare $v_h = \pi_x - \omega(h)$ when starting an x -project. Collecting all x -entrants gives aggregate welfare $\pi_x n_x - \Omega(n_x)$. We also suppose that y -startups getting a second chance have accumulated entrepreneurial experience which replaces the initial effort of fresh x -entrants. Since there are no other costs than effort of fresh x -entrants and equity investors, aggregate welfare is simply $V = \Pi - \Omega(n_x) - \theta e$. The social planner directly chooses the allocation and maximizes aggregate welfare subject to the resource constraints $n_x + n_y = 1$ and $d + e + A = I$,

$$V = \max_{q, n_x, e} \Pi - \Omega(n_x) - \theta e, \quad (20)$$

where $\Pi = pxn_x + \bar{y}(q)n_y + rA$ and $\bar{y}(q)$ by (11-13). Obviously, equity entails an effort cost and is more expensive so that $dV/de = -\theta < 0$ and $e^* = 0$ as in the market equilibrium.

The first-best allocation q^* and n_x^* must satisfy optimality conditions

$$\frac{dV}{dq} = [px(1-c) - q^*y]n_y = 0, \quad \frac{dV}{dn_x} = px - \bar{y}(q^*) - \omega(n_x^*) = 0. \quad (21)$$

Comparing with the bank's choice of the liquidation cut-off $q = pi'_x(1-c)/i_y$ and the loan rates in (19) and with the sectoral choice condition (9) implies:

Proposition 1 *If credit reallocation is unconstrained, the market equilibrium is efficient.*

Proof. Substituting for q in (21) using (17) yields $dV/dq = 0$ such that $q = q^*$. Substituting for n_x in the second condition using $\omega(n_x) = \pi_x - \bar{\pi}_y$ from (9) together with $\bar{\pi}_y = \bar{y}(q) - \pi_{by}$ and $\pi_{by} = pi_x = r$ yields $dV/dn_x = 0$ such that $n_x = n_x^*$. ■

Competitive banks propose a credit contract such that subsequent liquidation maximizes the joint surplus, and then scale down interest rates until they hit break-even. This is equivalent to welfare maximization. Similarly, zero profits of banks and investors imply that entrepreneurs capture the entire joint surplus. Given uniform refinancing costs r , the sectoral difference in joint surplus corresponds to the output difference in (21). Startup investment is therefore first-best as well.

3.2 Constrained Reallocation

Liquidating firms and reallocating credit impairs bank capital. When a bank liquidates, it must write off part of the credit and needs equity to absorb this loss. The bank risks to violate regulatory requirements or would even be insolvent if equity turned negative. In this situation, a bank with opaque assets in place is typically unable to rapidly issue new equity due to long delays and dilution costs, as is commonly assumed in the literature on capital regulation (e.g., Repullo and Suarez, 2013).

3.2.1 Market Equilibrium

Capital Requirements: The regulatory constraint requires that a bank's capital ratio must at no point fall short of the minimum capital requirement k . Each bank needs to

raise enough equity a priori to ensure that after absorbing liquidation losses it still satisfies the capital requirement,

$$e - cq n_y \geq k \cdot (n'_x + n'_y). \quad (22)$$

Initial equity net of liquidation cost, $e - cq n_y$, must not fall short of minimum capital which is a fraction k of total assets. After reallocation in the interim period, assets consist of initial and new credit $n'_x = n_x + (1 - c) q n_y$ to x -firms and remaining credit $n'_y = (1 - q) n_y$ to y -firms. Credit reallocation has two countervailing effects on the constraint: When a bank liquidates $q n_y$ loans, it must write off a part $c q n_y$, which immediately reduces equity. At the same time, required equity falls by $k c q n_y$ because liquidation reduces bank assets to $n'_x + n'_y = n_x + n_y - c q n_y < n_x + n_y$. This effect is weak and little equity is freed up if capital standards are low. The first, negative effect dominates. Credit reallocation thus causes a *net loss of equity* equal to $(1 - k) c q n_y$. Anticipating this, the bank must raise an additional capital buffer of similar size when lending to a y -firm.⁵ This buffer must be large if many loans are liquidated, liquidation is costly, and the minimum capital standard is low.

A special case of (22) with qualitatively similar implications is a solvency constraint with $k = 0$. Since banks with negative equity are not allowed to operate, reallocation requires positive equity to absorb liquidation costs and to avoid insolvency. Different from capital requirements, the required equity of zero is unaffected by reallocation. Hence, net and gross equity losses coincide, which requires an even larger capital buffer of $c q n_y$.

Reallocation: Banks choose the liquidation cut-off to maximize expected profit, conditional on loan rates and capital structure. After observing the success probabilities, banks maximize the expected value subject to capital requirements (22) per y -loan, giving

⁵An x -project is long-term and defaults at the end of period with probability $1 - p$. A y -project defaults with probability $1 - \bar{q}$ but, in addition, is liquidated in the interim period with probability q . When extending a credit of size 1 to an x -firm, the bank needs k units of equity to satisfy the regulatory constraint. The same credit to a y -firm requires more bank equity, i.e., $k + (1 - k) c q$.

the constrained problem

$$\pi_{by} = \max_q \int_q^1 q' i_y dq' + \int_0^q p i_x' (1 - c) dq' + \lambda \cdot [e - cq n_y - k n_x - k(1 - cq) n_y] / n_y. \quad (23)$$

The optimal cut-off is characterized by

$$p i_x' (1 - c) - q i_y = \lambda (1 - k) c \quad \Rightarrow \quad q = \frac{p i_x' (1 - c) - \lambda (1 - k) c}{i_y}. \quad (24)$$

The net marginal gain in interest earnings on a reallocated y -loan must match the cost of the extra capital buffer needed to cover the net equity losses from liquidation. As long as the constraint binds ($\lambda > 0$), the cut-off is smaller compared to the first best in (15). Banks thus liquidate less aggressively and continue lending to some borrowers despite poor prospects.

Lending and Capital Structure: In the first stage, banks raise equity and cut loan rates to compete for business until they hit break-even. Note bank profits π_b as in (16), $\pi_b = [p i_x - r] n_x + [\pi_{by} - r] n_y - \theta e$, and use $d\pi_{by}/de = \lambda/n_y$ from (23). Since the optimal use of equity must satisfy $d\pi_b/de = \lambda - \theta = 0$, the regulatory constraint binds as long as equity earns a premium. Using the binding constraint to substitute for e yields

$$\pi_b = [p i_x - \bar{r}] n_x + [\pi_{by} - \bar{r} - \theta (1 - k) cq] n_y, \quad \bar{r} \equiv (1 - k) r + k\rho = r + \theta k. \quad (25)$$

When the bank operates at the regulatory minimum, the weighted cost of capital is \bar{r} . Since a credit to a y -firm makes more intensive use of bank equity due to an extra buffer, the refinancing cost exceeds the common cost \bar{r} by $\theta(1 - k)cq$.

Competition drives down loan rates until interest earnings just match refinancing costs. The linearity of the problem implies zero bank profits on both types of loans. Loan rates to innovative firms are fixed by $p i_x = \bar{r}$. They are now higher due to the use of costly equity. Similar to the unconstrained equilibrium, banks must set the ratio and level of loan rates i_y and i_x' when offering credit to a y -firm. They first set an optimal ratio that maximizes the joint surplus by inducing optimal liquidation in the subsequent stage. Next, they scale down the level of loan rates to shift the maximized surplus entirely to

firms. These are the best deals that banks can offer since they maximize entrepreneurial profits subject to a break-even condition. Adding to the bank's surplus on a y -project in (25) the firm's profit $\bar{\pi}_y = \bar{y}(q) - \pi_{by}$ yields a joint surplus $S \equiv \bar{y}(q) - \bar{r} - \theta(1-k)cq$. This joint surplus is affected by loan rates exclusively via their effect on subsequent liquidation. The optimal cut-off satisfying $dS/dq = 0$ is

$$q = \frac{px(1-c) - (1-k)\theta c}{y}. \quad (26)$$

It reflects the benefits of continued lending qy relative to liquidation and new lending to an x -project. Having fixed q , and noting $\lambda = \theta$, the bank must now set loan rates i_y and i'_x so that the subsequent liquidation decision in (24) indeed supports the optimal cut-off. The first condition on optimal loan rates is thus

$$q = \frac{pi'_x(1-c) - (1-k)\theta c}{i_y}, \quad \pi_{by} = \bar{r} + (1-k)\theta cq = \bar{q}i_y(1-q) + pi'_x(1-c)q. \quad (27)$$

In shifting the joint surplus to firms, banks scale down the level of loan rates until they hit the break-even constraint. This leads to the second condition. Using the first equation to eliminate $pi'_x(1-c)$ in the second one and noting $\bar{q}(1-q) = (1-q^2)/2$ yields⁶

$$i_y = \frac{2}{1+q^2} \cdot \bar{r}, \quad i'_x = \frac{q \cdot i_y + (1-k)\theta c}{p(1-c)}. \quad (28)$$

Industry structure: Entry follows from sectoral choice with heterogeneous effort costs. It pins down startup investments n_x and n_y . Substituting for $\pi_x = px - \bar{r}$ and $\bar{\pi}_y = \bar{y}(q) - \pi_{by} = \bar{y}(q) - \bar{r} - (1-k)\theta cq$ gives

$$\omega(n_x) = \pi_x - \bar{\pi}_y = px - \bar{y}(q) + (1-k)\theta cq. \quad (29)$$

The extra cost of the capital buffer, $(1-k)\theta cq$, lowers the profit of a y -firm relative to an x -firm. The innovative sector attracts more firms until start-up costs become too high.

⁶In the first best without any constraint, no equity is used so that the equity premium cannot inflate financing costs. Setting $\theta = 0$ yields $\bar{r} = r$ and $i_y = \frac{2}{1+q^2}r$. The optimal cut-off in (26) becomes $q = \frac{px(1-c)}{y}$, leading to $i'_x = \frac{x}{y}i_y$. The solution in (28) collapses to the first best in (19).

Welfare: By (11) and (13), aggregate income is $\Pi = pxn_x + \bar{y}(q)n_y + rA$. The regulatory constraint is $e \geq k + (1 - k)cqn_y$ by (22-23). If the planner is not constrained, aggregate welfare maximization implies $e^* = 0$. In a second-best world, bank equity can no longer be set to zero but must satisfy minimum capital requirements, leading to the constrained problem

$$V = \max_{q, n_x} \Pi - \Omega(n_x) - \theta [k + (1 - k)cqn_y]. \quad (30)$$

Using $n_y = 1 - n_x$, a variation of the market allocation changes aggregate welfare by

$$\frac{dV}{dq} = [px(1 - c) - qy - (1 - k)\theta c]n_y, \quad \frac{dV}{dn_x} = px - \bar{y}(q) + (1 - k)\theta cq - \omega(n_x). \quad (31)$$

Comparing market equilibrium to constrained and first-best optima (31) and (21) yields

Proposition 2 *The market equilibrium is second-best, or constrained-efficient, as it maximizes welfare subject to the regulatory constraint. Compared to the first best, there are two distortions: insufficient liquidation and reallocation of loans, $q < q^*$, and excess entry in the innovative sector, $n_x > n_x^*$. The distortions disappear if the equity premium is zero or the bank is fully equity funded.*

Proof. In market equilibrium, a bank's liquidation cut-off implied by the credit contract is given by (26) which implies $dV/dq = 0$. Similarly, using the free entry condition (29) to replace $\omega(n_x)$ in (31) also leads to $dV/dn_x = 0$. Starting with the first-best allocation q^* and n_x^* as given by (21) yields $\left. \frac{dV}{dq} \right|_{q=q^*} = -(1 - k)\theta cn_y < 0$ and $\left. \frac{dV}{dn_x} \right|_{q=q^*, n_x=n_x^*} = (1 - k)\theta cq^* > 0$ in (31). Welfare increases by raising entry and reducing liquidation until the second-best allocation is achieved. The two allocations coincide only if either $\theta = 0$ or $k = 1$. ■

When facing a regulatory constraint, banks are too lenient and allow some firms in the downsizing sector to continue despite their rather poor prospects. The reason is that they must raise a capital buffer to absorb the losses in the interim period, which is associated with higher capital costs. It is thus optimal to liquidate less often to economize on costly

equity. This behavior can be interpreted as ‘Zombie’ lending. Furthermore, the expected profit from entering the downsizing sector, $\bar{\pi}_y = \bar{y}(q) - \bar{r} - (1 - k)\theta cq$, falls more than proportionately due to inefficient liquidation and higher refinancing costs.⁷ Borrowing rates are higher because lending to y -firms is more equity-intensive, whereas getting a second chance is less likely due to reduced credit reallocation. More entrepreneurs thus directly enter the innovative sector with even higher effort cost and lacking of talent. In consequence, expansion of the innovative sector shifts away from serial entrepreneurship and reallocation and relies too much on the entry of marginal firms with no experience and little talent (‘excess entry’). If investment shifts from reallocation towards startup investment, the net effect on expansion of the innovative sector is likely to be negative, as is emphasized by the discussion of (37) below. These distortions of the investment process are caused by the banking sector due to a combination of regulatory constraints and costly bank equity. If equity earned the same return as debt, credit reallocation and startup investment would be efficient.

Finally, the general model nests several special cases. First, when equity is no more expensive than deposits (case $\theta = 0$), the bank always raises a sufficiently large capital buffer. The regulatory constraint is slack, leading to first-best investment. Intuitively, the premium is the very reason why a trade-off exists between credit reallocation and the cost of building a buffer. Second, when banks are all-equity financed (case $k = 1$), credit reallocation does not affect the regulatory constraint (22) because actual and required equity fall by exactly the same amount and the net loss of equity is zero. The liquidation cut-off q is first-best. Although the higher cost of capital raises loan rates, $i_x = \rho/p$, $i'_x = 2\rho x/(1 + q^2)y$ and $i_y = 2\rho/(1 + q^2)$, relative sectoral profits are unchanged and entry is not distorted. The scenario points to high capital requirements and a low equity premium being substitutes in the sense that they both improve allocative efficiency. Third,

⁷Profits in both sectors fall when equity is more costly, leading to higher refinancing costs $\bar{r} > r$. Profits in the y -sector, however, fall more strongly since the required capital buffer creates an extra cost $(1 - k)\theta cq$ due to reallocation. Liquidation and reallocation are inefficiently reduced, leading to smaller gains from entering the y -sector, compared to the first best.

when the economy is rigid (case $c > px/[px + \theta(1 - k)]$), either equity or liquidation are so expensive that banks consider reallocation too costly, giving $q = 0$. This case describes a poor institutional environment where banks cannot fulfill their ‘Schumpeterian role’. The conditional success probability of a y -firm equals the average, $\hat{q} = E[q] = 1/2$, and the break-even condition pins down the loan rate $i_y/2 = \bar{r}$.

3.2.2 Comparative Statics

We study the impact of four shocks - c insolvency law, θ equity premium, k capital requirement, and x capital productivity in the innovative sector - on the reallocation of credit, the initial and final sectoral allocation, and aggregate productivity. From $\bar{r} = r + \theta k$, and the solutions $pi_x = \bar{r}$ and $\pi_x = px - \bar{r}$, we get

$$d\bar{r} = k \cdot d\theta + \theta \cdot dk, \quad p \cdot di_x = d\bar{r}, \quad d\pi_x = p \cdot dx - k \cdot d\theta - \theta \cdot dk. \quad (32)$$

An increasing equity premium and capital requirement boost refinancing costs and are passed on to a higher loan rate, which reduces expected profit of an x -firm. Turning to y -firms, the liquidation rate changes by

$$dq = \frac{p(1-c)}{y} \cdot dx - \frac{px + (1-k)\theta}{y} \cdot dc - \frac{(1-k)c}{y} \cdot d\theta + \frac{\theta c}{y} \cdot dk. \quad (33)$$

The rate of credit reallocation $(n'_x - n_x)/n_y = (1-c)q$ increases if banks aggressively liquidate loans and the liquidation cost is smaller. Hence, a larger amount of funds is released which can be invested in new x -firms. Banks will liquidate more aggressively when innovative firms offer higher earnings (pull effect). A higher liquidation cost lowers the benefit from reallocation because it shrinks the released funds for new lending and, in addition, forces the bank to shift refinancing to more expensive equity to comply with capital regulation. A higher equity premium also limits liquidation since the necessary capital buffer is more expensive. A tighter regulatory stance, in turn, eases the limits to reallocation. Liquidation directly destroys equity by c . As the bank’s assets also shrink by c , the required regulatory capital falls by kc . The net loss of equity $(1-k)c$ becomes

smaller if the standard k is higher, leading banks to liquidate more aggressively.⁸

Competition forces banks to offer favorable credit terms which maximize expected firm profits. The entire joint surplus goes to firms, $S = \bar{\pi}_y = \max_q \bar{y}(q) - \bar{r} - (1 - k)\theta cq$, as noted prior to (26). Using the Envelope theorem gives

$$d\bar{\pi}_y = -[k + (1 - k)cq] \cdot d\theta - (1 - cq)\theta \cdot dk + p(1 - c)q \cdot dx - [px + (1 - k)\theta]q \cdot dc. \quad (34)$$

More expensive equity, higher liquidation costs and tighter capital requirements inflate costs and shrink the expected profit of a y -firm, whereas a higher return x boosts the value of a fresh start.

The consequences for startup investment depend on how shocks affect expected firm profits. Noting $\omega' > 0$, the sectoral choice condition (29) yields $\omega' \cdot dn_x = d\pi_x - d\bar{\pi}_y$ or

$$dn_x = \frac{(1 - k)cq}{\omega'} \cdot d\theta + \frac{[px + (1 - k)\theta]q}{\omega'} \cdot dc - \frac{\theta cq}{\omega'} \cdot dk + \frac{p[1 - (1 - c)q]}{\omega'} \cdot dx. \quad (35)$$

Intuitively, the x -sector is less intensive in bank equity as no extra buffer for liquidation is needed. Hence, expected profit shrinks relatively less when equity gets more expensive which pushes firms into this sector. Similarly, higher liquidation costs make bank lending to y -firms more intensive in costly equity. In addition, liquidation releases less funds for new lending and thereby reduces the possibility to get a second chance. Entrepreneurs thus prefer to start an x -firm right away even with somewhat less talent and higher entry costs, instead of acquiring experience in the y -sector and counting on a second chance upon liquidation. Tighter capital requirements make lending to both types of firms more intensive in costly equity. However, they reduce the differential refinancing cost of y -loans

⁸Adding a constraint leads to the second best and reduces liquidation. However, once the restriction is imposed, a solvency constraint ($k = 0$) imposes the largest marginal cost on liquidation. It requires the largest buffer per project to back up liquidation losses cq in advance. With higher k , shrinking bank assets reduce the *net* buffer to $(1 - k)cq$. Hence, $k \rightarrow 1$ leads to the first best. However, the use of bank equity makes financing of firms more expensive, at the expense of entrepreneurs. Since the total number of entrepreneurs is fixed, no other distortion is created. If not only sectoral allocation but also the level of investment were endogenous, fully equity financed banks could not be the solution.

since a smaller voluntary buffer is needed with higher capital standards. Better relative credit conditions cause profits of y -firms to shrink by less than that of x -firms. Finally, a higher output x attracts more entrepreneurs to the x -sector.

Sectoral investment in (6) reflects entry and reallocation. Using $dn_y = -dn_x$ gives

$$dn'_x = [1 - (1 - c)q] \cdot dn_x + [(1 - c)n_y \cdot dq - qn_y \cdot dc]. \quad (36)$$

Expansion of the innovative sector is driven by a level effect resulting from entry as in the first term and by a reallocation effect as in the second term. Substituting (33) for dq and (35) for dn_x and using the entry elasticity $\eta \equiv [1 - (1 - c)q]q/\omega'$ and the reallocation elasticity $\mu \equiv (1 - c)n_y/y$ yields

$$\begin{aligned} dn'_x = & p [\eta (1 - (1 - c)q) / q + \mu (1 - c)] \cdot dx \\ & - [qn_y + (\mu - \eta) (px + (1 - k)\theta)] \cdot dc \\ & + (\mu - \eta) [\theta c \cdot dk - (1 - k)c \cdot d\theta]. \end{aligned} \quad (37)$$

Better investment opportunities with a higher return x accelerate the innovative sector's growth by boosting entry and reallocation.

With other shocks, entry and reallocation tend to offset each other. If entry is relatively inelastic (ω' large), the net effect is dominated by reallocation, $\mu > \eta$, so that investment is flexibly redirected whenever relative prospects change. We emphasize this scenario of 'Schumpeterian banks' as motivated in the introduction. In the opposite case with $\omega' \rightarrow 0$, investment depends relatively less on credit reallocation. Specifically, a higher liquidation cost c slows down reallocation and locks up investment in the downsizing sector: First, there is a *mechanical* effect for any given entry and liquidation rate. When more capital is destroyed in liquidation procedures due to inefficient insolvency laws, banks can extract less capital from unprofitable firms so that the flow of reallocated credit shrinks by $-qn_y dc$. Turning to the induced *behavioral* effects, banks liquidate less often when it becomes more costly. Accordingly, only few funds are released in the downsizing industry and less capital is redirected to fund additional x -projects. The strength of this effect is captured by the elasticity μ . On the other hand, more costly liquidation procedures inflate total

investment costs and, thereby, reduce expected profit from starting y -projects, see (34). In consequence, startup activity shifts from the traditional to the innovative sector as noted in (35) which partly compensates for reduced credit reallocation. The strength of this effect depends on the entry elasticity η . Given our main scenario of $\mu > \eta$, the net behavioral effect reinforces the direct mechanical effect of higher liquidation costs.

Bank regulation can importantly affect sectoral investment. The key point is that investment in the downsizing industry is more intensive in bank equity, which is more expensive than deposit funding. Banks need to raise a voluntary buffer to absorb possible liquidation losses without violating capital requirements. No such buffer is needed in funding innovative projects which are long-term without any interim performance signal that might call for premature liquidation. If regulators raise the capital standard k , banks choose to liquidate more aggressively, see (26). The reason is that liquidation also shrinks assets on a bank's balance sheet which reduces the *net* required equity buffer to a larger extent if capital standards are higher. Higher capital standards thus boost credit reallocation which expands investment in the innovative sector by $\mu\theta cdk$. On the other hand, they directly raise funding costs and thereby contribute to lower expected profit of firms in both sectors. They reduce expected profits of x -firms by $d\pi_x = -\theta dk$ while the effect on y -firms is only $d\bar{\pi}_y = -(1 - cq)\theta dk$. In relative terms, starting a firm in the downsizing sector becomes more attractive. Startup investment shifts away from the expanding sector by $dn'_x = -\eta\theta cdk$. As long as entry is inelastic, the net effect remains positive. Raising capital standards thus favors investment in the innovative sector.

A higher cost of equity due to a rising premium θ triggers opposite effects. Banks liquidate non-performing loans less frequently to economize on the expensive equity buffer. This slows down reallocation and locks up investment in the downsizing industry. On the other hand, the need for a capital buffer makes funding of y -projects more expensive. As the equity premium rises, relative funding costs diverge even more which renders y -projects less attractive and shifts startup activity towards the innovative sector. A modest entry elasticity makes the reallocation effect dominate. A higher cost of bank equity thus

impairs innovative investment.

Efficient resource allocation is a key source of aggregate factor productivity. Productivity rises when capital flows smoothly from declining towards expanding firms where it generates higher returns. In the present framework with a mass one of firms, $n_x + n_y = 1$, each investing one unit of capital, aggregate capital productivity is $\bar{z} \equiv px \cdot n_x + \bar{y}(q) \cdot n_y$, see (11). Expected output of an x -sector startup exceeds that of a firm entering the y -sector, $px > \bar{y}(q)$. Productivity thus depends on the sectoral allocation of startup investment and of subsequent reallocation in all events where continuation in the y -sector is no longer profitable. Appendix A calculates the change in productivity,

$$\begin{aligned}
d\bar{z} = & \left[(n_x + (1-c)qn_y) + (1-c)\tilde{\mu} + \frac{1-(1-c)q}{q}\tilde{\eta} \right] p \cdot dx \\
& - [pxqn_y + (\tilde{\mu} - \tilde{\eta})[px + (1-k)\theta]] \cdot dc \\
& + (\tilde{\mu} - \tilde{\eta})\theta c \cdot dk - (\tilde{\mu} - \tilde{\eta})(1-k)c \cdot d\theta,
\end{aligned} \tag{38}$$

where $\tilde{\mu}$ and $\tilde{\eta}$ capture the effects of reallocation and initial sectoral choice on productivity, and where $\tilde{\mu} > \tilde{\eta}$ as long as liquidation costs c are not excessively high.

Intuitively, reallocation cannot add much to productivity when too much capital is lost in the liquidation process. The interpretation is similar to (37). Higher returns x *mechanically* boost aggregate productivity which is reinforced by *behavioral* effects since the shock attracts initial entry as well as reallocation towards the highly productive x -sector. A higher liquidation cost *mechanically* reduces productivity as more capital is wasted in the bankruptcy of inefficient y -entrants. The erosion of productivity is magnified by the fact that higher liquidation costs block reallocation towards more productive uses. On the other hand, a higher cost reduces the profitability of y -firms and shifts startup activity towards the x -sector. The net behavioral response reinforces the direct mechanical effect. Tighter capital standards facilitate reallocation and boost aggregate productivity. Alternatively, policy makers could aim at lowering the cost of bank equity, leading to similar productivity gains. Summarizing the main findings establishes:

Proposition 3 *In the presence of a regulatory constraint,*

- *a higher equity premium θ reduces reallocation but shifts entry towards the x -sector. Total investment in the innovative sector declines and aggregate productivity falls;*
- *a tighter capital requirement k magnifies reallocation but discourages entry in the x -sector. Total innovative sector investment and aggregate productivity rise;*
- *a higher liquidation cost c reduces x -sector investment and aggregate productivity. These effects are magnified by investment shifting from reallocation to entry;*
- *a higher return x mechanically boosts productivity. Investment in the x -sector expands on both reallocation and entry margins which magnifies productivity gains.*

Proof. Immediately follows from (33), (35), (37) and (38). ■

In our framework, the main distortions caused by the banking sector are insufficient loan liquidation and biased sectoral choice. Total investment in the innovative sector shifts from reallocation towards startup activity with little experience and high effort cost. Among the policy options to correct these distortions are tighter capital standards and measures to reduce the cost of bank equity, making banks better capitalized and more resilient in absorbing liquidation losses. Lowering the cost of equity relative to deposit financing appears to be a preferred option. This may involve, for example, better investor protection and transparency to the benefit of the investors' effort in supervision and control. Tax reform could eliminate the debt bias in corporate taxation which raises the cost of equity relative to deposits. Eventually, reforming insolvency laws could help banks to recover more capital in the liquidation process which increases available funds for new lending to projects with better prospects.

3.2.3 Testable Predictions

The main predictions can be tested in different empirical settings, especially in Europe where banks rather than capital markets are the dominant funding source for business investment. Ideally, one has access to loan-level data about bank-firm relationships, for

example, from a credit register. The focus would be on small and medium sized firms which are predominantly bank-dependent. The main predictions are established in Proposition 3. For example, the probability of terminating a loan to a weak firm in a declining sector - the liquidation rate q - increases in the quality of insolvency law (lower c) and in profitability of firms in R&D intensive expanding sectors (higher x). It also rises in the minimum capital requirements or capital buffer of banks (higher k) but falls with a higher cost of equity (higher θ). In our model, weak firms are characterized by a low success probability. Following Schivardi et al. (2017), firms can be classified as high-risk according to their leverage. To capture firms operating in downsizing parts of the economy, one might focus on those industries with low productivity (e.g., measured by the average return on assets) or low average R&D expenditures. In the regression, this ‘Zombie’ measure could be interacted with the explanatory variables of interest.

A first attempt would be to directly estimate the effect of the bank’s (regulatory) capital ratio or buffer on the outcome variables. One expects to find a positive effect on the probability of loan termination (extensive margin) and a negative one on credit growth (intensive margin). Since our model fully endogenizes the capital buffer, one can replace the actual capital ratio with its two key determinants, i.e., the capital requirement and the cost of equity. A major challenge is that there is little variation in capital requirements as they apply in the same way to all banks in a country. Following a common strategy in existing research, one could exploit the inherent heterogeneity in Basel II and III. The computation of risk weights implies loan-specific capital requirements since firms differ in risk and banks differ in the models used to evaluate risks, as emphasized by Fraise et al. (2015). One could also exploit regulatory discretion as suggested by Aiyar et al. (2015). Such discretion has been common practice in the UK, for example. The equity premium, or more generally, the opportunity cost of equity can be measured by the bank’s return on equity (Ayuso et al., 2004) or by the ratio of Tier 1 to total regulatory capital as suggested by Francis and Osborne (2012). A proxy for alternative investment opportunities could be the average return on assets of firms in R&D-intensive industries. To capture the effect of insolvency laws, one could exploit differences that exist depending on the firm’s legal

form, or cross-country variations in the quality of bankruptcy procedures.

Not only is our model informative about terminating loans to ‘Zombie’ firms, it also predicts that new loans to profitable firms - credit reallocation $(1 - c)q$ - rises in capital requirements, quality of insolvency law, and investment returns in innovative sectors but falls with higher costs of bank equity. Firms could be classified as (potentially) expanding based on the productivity or R&D intensity in their industry, leverage or firm age. One can test this prediction in a similar way like loan liquidation.⁹ Together, the estimates for loan liquidation and new lending to more profitable firms provide evidence about the mechanism of credit reallocation and the role of bank characteristics.

Our theoretical analysis compares the market allocation with an unconstrained benchmark and finds that innovative sector investment hinges too much on startup activity and too little on credit reallocation and serial entrepreneurship. Capital is locked up in firms that turn out to be unprofitable, and fails to flow to more profitable ones. The prediction is that the efficiency of capital allocation should rise with better insolvency laws, tighter capital standards and lower cost of bank equity. In theory, final investment n'_x , the liquidation rate q , and entry n_x move closer to their first-best levels. This prediction might be tested using Wurgler’s (2000) measure of allocative efficiency - the elasticity of investment to value added. Since this variable is aggregated at the country level, one would need cross-country data. Capital requirements can be approximated by an index measuring the stringency of capital regulation (e.g., Barth et al., 2013), the cost of equity by banks’ average return on equity, and insolvency laws by a typical index.

Eventually, one can adopt a similar approach to test the predictions for productivity using a country- or industry level proxy of capital productivity like Tobin’s q , investment rate, or capital utilization as the dependent variable.¹⁰ The theoretical analysis showed that aggregate productivity tends to increase in capital standards and the quality of insolvency laws and the decrease in the cost of bank equity.

⁹A broader measure of the quality of insolvency laws is necessary since the liquidation value of shrinking firms is independent of the legal form of innovative firms. This may require cross-country data.

¹⁰See Eisfeldt and Rampini (2006) who discuss several measures of capital productivity.

4 Conclusion

An efficient financial sector promotes the process of creative destruction by withdrawing funds from declining firms and reallocating them to more productive ventures. The paper provides a first theoretical analysis of the process of credit reallocation and specifically focuses on the role of banks' capital structure. In our framework, banks liquidate loans when monitoring reveals poor prospects for success and full repayment. Liquidation releases locked up funds which banks can reallocate to new projects with better prospects. However, liquidation causes losses which impair their equity and might lead to a violation of regulatory requirements. Given that recapitalization is especially difficult at a time of distress, we present a novel motivation for voluntary capital buffers. Building up such buffers a priori allows banks to realize losses in the reallocation process without violating capital requirements. If equity is more expensive than alternative sources of funding, however, banks economize on the use of equity and capital buffers are small.

Low equity of banks distorts aggregate investment in two ways: First, banks are hesitant to liquidate non-performing loans which blocks credit to profitable firms and thereby slows down the expansion of innovative industries. Tight capital buffers limit banks' ability to aggressively close down unprofitable firms and reallocate credit to more productive uses. Instead, they engage in 'Zombie' lending and keep loans to non-viable firms. This finding is broadly consistent with evidence from Japan (Peek and Rosengren, 2005) and, more recently, from Europe (Acharya et al., 2015; Schivardi et al., 2017). Second, reduced credit reallocation distorts startup investment across sectors. If the alternative route of entering the traditional sector, accumulating business experience and trying later on a fresh-start in the innovative sector is blocked, too many entrepreneurs enter the innovative sector right from the beginning despite little talent and high entry costs. Importantly, this behavior also impairs aggregate productivity.

Governments can alleviate these frictions and ease the process of creative destruction in several ways. They could aim at making bank equity more available and less expensive by abolishing tax distortions and improving the standards of investor protection. Tight-

ening minimum capital requirements can boost the ability of banks to absorb losses from liquidation or restructuring. They could also reform insolvency laws to lower liquidation costs and facilitate fresh starts.

Appendix

A. Aggregate Productivity To derive (38), take the differential of the productivity measure $\bar{z} \equiv pxn_x + \bar{y}(q)n_y$,

$$d\bar{z} = pn_x \cdot dx + n_y \cdot d\bar{y} + (px - \bar{y}) \cdot dn_x. \quad (\text{A.1})$$

Substituting $d\bar{y} = p(1-c)q \cdot dx - pxq \cdot dc + [px(1-c) - yq] \cdot dq$ yields

$$d\bar{z} = p[n_x + (1-c)qn_y] \cdot dx - pxqn_y \cdot dc + [px(1-c) - yq]n_y \cdot dq + (px - \bar{y}) \cdot dn_x. \quad (\text{A.2})$$

The reallocation effect is positive since $px(1-c) - yq = \theta(1-k)c > 0$ by (26). The entry effect is also positive. The sectoral choice condition $\pi_x - \bar{\pi}_y = \omega(n_x) > 0$ requires $px > \bar{y}$ in the first best. Since the first-best loan contract by construction maximizes \bar{y} as in (17), the condition is automatically satisfied in the second best.

The final effects in (38) obtain when substituting for the behavioral effects dq and dn_x in (33) and (35) and using the definitions

$$\tilde{\mu} \equiv \frac{px(1-c) - yq}{1-c} \cdot \mu, \quad \tilde{\eta} \equiv \frac{px - \bar{y}}{1 - (1-c)q} \cdot \eta. \quad (\text{A.3})$$

Finally, we need to show $\tilde{\mu} > \tilde{\eta}$. The assumption of $\mu > \eta$ as discussed in (37) implies $\tilde{\mu} > \tilde{\eta}$ a fortiori if the first inequality in (A.4) holds. Using $px - \bar{y} = px[1 - (1-c)q] - \bar{q}y(1-q)$ and $\bar{q}(1-q) = (1-q^2)/2$ yields

$$\frac{px(1-c) - yq}{1-c} > \frac{px - \bar{y}}{1 - (1-c)q} \Leftrightarrow (1-c) \frac{1+q^2}{2} > q. \quad (\text{A.4})$$

For $c \rightarrow 0$, the inequality is equivalent to $1 - 2q + q^2 > 0$ or $(1-q)^2 > 0$. By continuity, condition (A.4) also holds for positive, but sufficiently small values of c so that $\mu > \eta$ implies $\tilde{\mu} > \tilde{\eta}$ a fortiori. Even if c is further increased and starts to violate (A.4), $\tilde{\mu} > \tilde{\eta}$ still holds due to $\mu > \eta$ as long as (A.4) is not reversed ‘too much’.

B. A Signaling Model of Credit Reallocation We assumed that banks observe the success probability. Although they have special monitoring expertise, banks cannot perfectly assess loan quality. To check for robustness, we relax this assumption and introduce imperfections in loan assessment similar to Inderst and Mueller (2008). In the beginning, banks know that a fraction β of firms will succeed and a fraction $1 - \beta$ will fail but they cannot identify the specific type of any individual y -firm. In the interim period, monitoring yields an imperfect but informative performance signal $s' \in [0, 1]$. It is drawn from type-specific distributions with cumulative density functions $F_H(s')$ and $F_L(s')$ where $F_H(s')$ first-order stochastically dominates $F_L(s')$. Density functions satisfy $f_H(0) = 0$ and $f_L(0) > 0$ as well as $f_H(1) > 0$ and $f_L(1) = 0$. Monitoring is more likely to yield a good signal if the firm is a successful type. The posterior belief (the probability that a y -firm is a successful type conditional on the signal) is

$$\beta(s') = \frac{\beta f_H(s')}{\beta f_H(s') + (1 - \beta) f_L(s')}. \quad (\text{B.1})$$

Note that $\beta(0) = 0$ and $\beta(1) = 1$. By first-order stochastic dominance, the revised success probability increases in the signal, $\beta'(s') > 0$.

Banks liquidate a y -loan if monitoring reveals a weak performance signal $s' < s$ where s is the cut-off. In total, they liquidate a share $H(s) \equiv \beta F_H(s) + (1 - \beta) F_L(s)$ of loans. Importantly, monitoring yields only imperfect information and leads to errors. Banks end up terminating a share $F_H(s)$ of good loans and erroneously prolong a share $1 - F_L(s)$ of bad loans. Loan liquidation determines the ex ante success probability of a y -firm¹¹

$$\hat{q}(s) = \int_s^1 \beta(s') dH(s') = \beta[1 - F_H(s)]. \quad (\text{B.2})$$

A share $\beta[1 - F_H(s)]$ of firms is both successful and allowed to continue. The success probability, conditional on not being liquidated, is

$$\bar{q}(s) = \frac{\int_s^1 \beta(s') dH(s')}{1 - H(s)}. \quad (\text{B.3})$$

¹¹Using $h(s') = \beta f_H(s') + (1 - \beta) f_L(s')$ and (B.1) yields the second equality by calculating $\int_s^1 \beta(s') h(s') ds' = \int_s^1 \beta f_H(s') ds' = \beta[1 - F_H(s)]$.

To sum up, the probability $\beta(s')$ corresponds to q' in the base model, the share of liquidated firms is $H(s) = \int_0^s h(s') ds'$ versus $q = \int_0^q dq'$, the unconditional success probability is (B.2) versus $\hat{q}(q) = \int_0^q dq'$ and the conditional probability in (B.3) corresponds to $\bar{q}(q) = \int_q^1 q' dq' / (1 - q)$. Noting these correspondences, the solution proceeds exactly as in the main text. Banks collect liquidation proceeds of $(1 - c) H(s) n_y$. Instead of (6), final investment equals $n'_x = n_x + (1 - c) H(s) n_y$ and $n'_y = n_y - H(s) n_y$. The regulatory constraint in (22) is now $e - cH(s) n_y \geq k \cdot (n'_x + n'_y)$. To illustrate further, we repeat the bank's liquidation decision in (23),

$$\pi_{by} = \max_s \hat{q}(s) i_y + p i'_x (1 - c) H(s) + \lambda \frac{e - cH(s) n_y - k n_x - k (1 - cH(s)) n_y}{n_y}. \quad (\text{B.4})$$

Optimality $p i'_x (1 - c) - \beta(s) i_y = \lambda (1 - k) c$ yields the same cut-off as in (24),

$$\beta(s) = \frac{p i'_x (1 - c) - \lambda (1 - k) c n_y}{i_y}. \quad (\text{B.5})$$

In the first stage, banks raise equity and compete for borrowers to maximize expected profit $\pi^b = p i_x n_x + \pi_{by} n_y - r(n_x + n_y) - \theta e$. Given $d\pi_{by}/de = \lambda/n_y$ from (B.4), optimality $d\pi^b/de = \lambda - \theta = 0$ implies that the capital constraint binds. Substituting for e yields

$$\pi_b = [p i_x - \bar{r}] n_x + [\pi_{by} - \bar{r} - \theta (1 - k) cH(s)] n_y, \quad \bar{r} \equiv (1 - k) r + k\rho = r + \theta k. \quad (\text{B.6})$$

Competition drives down loan rates until break even, i.e., $p i_x = \bar{r}$ and

$$\pi_{by} = \hat{q}(s) i_y + p i'_x (1 - c) H(s) = \bar{r} + (1 - k) \theta cH(s). \quad (\text{B.7})$$

Competition forces banks to cede the entire joint surplus to firms. The profit of a y -startup is $\bar{\pi}_y = \bar{y}(s) - \pi_{by}$ with $\bar{y}(s) = \bar{q}(s) y [1 - H(s)] + p x (1 - c) H(s)$. Adding the bank's profit $\pi_{by} - \bar{r} - \theta (1 - k) cH(s)$ yields a joint surplus $S(s) = \bar{y}(s) - \bar{r} - (1 - k) \theta cH(s)$. Intuitively, banks attract customers by leaving them higher profits which leads them to maximize the joint surplus. Noting (B.3), the cut-off s must satisfy

$$\beta(s) = \frac{p x (1 - c) - (1 - k) \theta c}{y}, \quad (\text{B.8})$$

which exactly corresponds to (26) in the base model. Banks scale down interest rates i_y and i'_x to satisfy two conditions, to break-even on a y -loan and to support optimal liquidation (B.8) by the subsequent choice in (B.5). None of our results are affected by keeping with the simpler model in the main text.

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