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JEL Classification: E23, E44, G21, O4

Keywords: N/A

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Banks, Credit Reallocation, and Creative Destruction*

Christian KEUSCHNIGG†, Michael KOGLER‡, and Johannes MATT§

This version: November 8, 2022

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1 Introduction

Creative destruction requires that scarce resources flow from obsolete structures to more productive uses. As argued by Schumpeter (1911, pp. 370-1), one of the main functions of banking is to allocate capital based on firm productivity. As major financiers of investment, banks often establish long-term lending relationships with firms and are inevitably confronted with some borrowers who are likely to fail. By restructuring such non-performing loans and shifting the released funds to new ventures, banks alleviate financial constraints and contribute to the reallocation of capital to the most productive firms.

This paper analyzes how banks can facilitate creative destruction and shape firm turnover. We focus on how banks restructure, that is, prematurely liquidate, non-performing loans, which is not only an important determinant of firm exit but also releases funds for the financing of new firms. We study the decision of banks whether to restructure a loan and explore the effects of credit reallocation on the economy at large, for instance, on aggregate productivity, output, and consumption. Our analysis also sheds light on policy complementarities between firm entry and exit margins.

Our approach combines theoretical and quantitative analysis: We embed a structural model of bank credit reallocation into a dynamic general equilibrium framework with endogenous firm creation and exit. The model is calibrated to match key moments of firm dynamics, loan quality, and capital structure. Our model of firm turnover is inspired by Acemoglu et al. (2018): Firms gradually fall back from the technological frontier before being hit by a destructive shock. Banks continuously monitor and receive a signal about each firm's prospects and credit risk. If a destructive shock is likely, the bank may restructure a loan, which releases part of the funds for lending to new firms.

The notion of reallocation is only meaningful in the presence of scarcity. We emphasize the availability of deposits as the key resource constraint of the economy. After all, deposits are a stable and cheap funding source, and access to deposits is a critical determinant of credit supply as documented by a large stock of empirical research (Becker, 2007; Ivashina and Scharfstein, 2010; Drechsler et al., 2017; Doerr et al., 2022). Following an established approach in the macro finance literature (Van den Heuvel, 2008; Christiano et al., 2010;

Begenau, 2020), we introduce a preference for liquid assets that creates a 'convenience yield' on deposits. Even in a steady state, deposits are inelastic to some extent, and the interest rate thus rises whenever households accommodate a larger demand for deposits.

Our analysis yields three main results: First, improving the efficiency of the loan restructuring process, for instance, by reforming insolvency laws, not only accelerates the exit of unproductive firms and improves aggregate productivity as banks liquidate more non-performing loans. It also fosters the creation of new firms by relaxing the aggregate resource constraint that originates from scarce deposits. Banks reallocate more outstanding loans and become less dependent on deposits. This leads to a drop in the equilibrium interest rate that is pronounced whenever households supply deposits inelastically as implied by the empirical evidence (Chiu and Hill, 2018). Competitive banks pass the lower borrowing costs on to firms, attracting additional entrants.

Second, we highlight a policy complementarity between firm entry and exit margins that is especially strong whenever deposits are inelastic. Stimulating firm creation, for example, with R&D subsidies for start-ups, ultimately raises the equilibrium deposit rate. This crowds out some of the new investments, making this policy rather ineffective. Combining the R&D subsidy with improved loan restructuring helps avoid such a crowding-out by facilitating exit of unproductive firms.

Third, our quantitative simulations point to sizable discrete effects of bank credit reallocation compared to a counterfactual scenario in which banks altogether refrain from restructuring loans. Aggregate productivity, for example, increases by 3.2 percent and consumption increases by up to 3.4 percent. The aggregate gains are large whenever the economy's resource constraint is tight due to more inelastic deposits. Imperfect information in bank monitoring, however, prevents the economy from exploiting the full gains because banks only receive a noisy signal about the borrower's true credit risk as in Inderst and Mueller (2006, 2008). This causes type I/II errors in their liquidation decisions. Eliminating such imperfections would allow banks to precisely identify all non-performing loans without costly errors. In such a frictionless economy, aggregate output could be between 9 and 18 percent and consumption even between 30 and 38 percent higher. This compares well with the findings of the misallocation literature discussed below.

Our paper connects to three main strands of research in the intersection of finance and macroeconomics. First, the literature on capital reallocation shows that the amount of reallocated capital is sizable and accounts for roughly 25 to 30 percent of annual investment in the U.S. Existing research typically models the reallocation or liquidation decisions at the firm level and emphasizes constraints and frictions that impede reallocation. Examples are Eisfeldt and Rampini (2006) who develop a model with capital illiquidity to explain the cyclical patterns of capital reallocation, Eisfeldt and Rampini (2008) who study the effects of managerial incentives and compensation on reallocation decisions, and Cui (2022) who argues that adverse financial shocks may delay the capital liquidation by raising the entrepreneur's option value of remaining in the market.

The closely related misallocation literature highlights large aggregate productivity gains from reallocating resources from low- to high-productivity firms. Evidence by Hsieh and Klenow (2009) suggests that China and India could increase aggregate TFP in manufacturing by 30-60 percent if capital and labor were allocated across firms like in the United States. Large productivity dispersion across firms, however, implies that many potential gains from reallocation remain unexploited and points to frictions that cause misallocation (Syverson, 2004a,b; Hsieh and Klenow, 2009). Evidence from Southern Europe suggests that the misallocation of capital has increased and depressed productivity growth after the global financial crisis (Gopinath et al., 2017).

Our analysis is largely complementary to this research but takes an entirely different route: We study the reallocation decisions of banks rather than firms and focus on their restructuring of non-performing loans. Given their often long-standing lending relationships with firms, banks play a key role in insolvency procedures, which should affect the exit margin and feed back on entry decisions. In our model, redirecting existing credit alleviates funding pressure higher up in the productivity distribution, leading to reallocation towards more productive firms and aggregate productivity gains. Moreover, banks face different constraints and frictions that influence their liquidation decisions than firms. Unlike existing research that predominantly focused on firm-level financial constraints as a source of capital misallocation, we emphasize frictions in the financial intermediation process, in particular, imperfect information in bank monitoring that leads to inefficient liquidation decisions.

Second, our paper relates to the literature on creative destruction (Aghion and Howitt, 1992, 1996), and more specifically the literature on how financial intermediation fosters or hampers creative destruction. Aghion et al. (2019) identify countervailing effects of credit access on productivity growth: While better access to credit makes it easier for entrepreneurs to innovate, it also allows less efficient incumbents to remain in the market for longer, thereby discouraging entry of potentially more efficient innovators. In an analysis of US banking deregulation, Kerr and Nanda (2009) find evidence that such reforms improved access to credit for young firms, entry into entrepreneurship as well as firm exit.

In this spirit, we focus on financial intermediaries and integrate a full-fledged model of banks into a framework of endogenous firm creation and destruction. By restructuring loans to unproductive firms with high default risk and redirecting credit to more productive entrants, banks play an essential role in facilitating creative destruction. This mechanism is consistent with empirical evidence by Gropp et al. (2022) and Hardy and Sever (2021), who point to long-lasting adverse effects of banking crises on innovation and productivity growth, and Schmidt et al. (2020), who argue that misallocation caused by weak banks impedes corporate innovation.

Third, the literature on 'zombie lending' argues that under-capitalized banks are a major source of inefficiencies at the firm exit margin: They often continue lending to quasi-insolvent borrowers to avoid write-offs that would further impair their already low equity. This behavior is well documented in the empirical literature: Prominent examples are Japan's 'lost decade' during the 1990s (Peek and Rosengren, 2005; Caballero et al., 2008) and parts of Southern Europe after the global financial crisis (Acharya et al., 2019; Blattner et al., 2019; Schivardi et al., 2022). The incentives for 'zombie lending' tend to be stronger if inefficient insolvency regimes inhibit corporate restructuring as shown by Andrews and Petroulakis (2019). Banking theory explains this phenomenon by risk shifting (Bruche and Llobet, 2014; Homar and van Wijnbergen, 2017) and by the interaction between loan liquidation losses and regulatory constraints (Keuschnigg and Kogler, 2020, 2022).

'Zombie lending' slows down the exit of unproductive firms. It thereby hampers reallocation and may impair aggregate productivity growth. The literature emphasizes market congestion as the key mechanism through which 'zombie firms' crowd out investment of healthy, more productive firms and create barriers to entry (Caballero et al., 2008; Andrews and Petroulakis, 2019; Adalet McGowan et al., 2018). Andrews and Petroulakis (2019) provide direct evidence of reduced availability of bank credit in industries with many 'zombie firms'. By characterizing the optimal liquidation decision, we shed light on why banks continue some loans despite low productivity and high risk of failure and emphasize the role of monitoring imperfections and liquidation costs.

Unlike existing theoretical work on 'zombie lending', which has predominantly been partial equilibrium (Bruche and Llobet, 2014; Homar and van Wijnbergen, 2017; Keuschnigg and Kogler, 2020), we embed a meaningful model of bank loan restructuring in a general equilibrium framework with creative destruction. We are thus able to theoretically and quantitatively explore the aggregate effects of bank behavior at the exit margin on firm turnover and productivity. Furthermore, we endogenously determine the crowding-out of new firms via higher borrowing costs in general equilibrium. This mechanism, driven by financial frictions, reflects the argument of 'zombie congestion' emphasized, for example, by Caballero et al. (2008) and Adalet McGowan et al. (2018).

The remainder of this paper is organized as follows: Section 2 sets out the model, and Section 3 derives the analytical results. Section 4 discusses calibration, and Section 5 provides the quantitative findings. Section 6 concludes.

2 Model

2.1 Firms

There are two groups of firms: *Production firms* use one unit of capital and one product design to generate output. They experience technological decay and destructive shocks. *Start-ups* conduct R&D to develop product designs sold to new producers. Their research output determines firm creation.

Production Firms: Entrants are at the technological frontier and generate output y^h per period (h-types). At any point in time, with probability $1-\omega$, h-firms may be hit by a negative productivity shock that permanently reduces per-period output to $y^\ell < y^h$. Firms in this low-productivity state (ℓ-types) are subject to destruction shocks that reduce output to zero with probability $1-q$. In this case, capital depreciates to a residual value $z < 1$, and the firm defaults and exits. Firms may also exit if banks prematurely stop funding ℓ-firms when restructuring loans. The survival rate of an ℓ-firm ϕ_{t-1} reflects exogenous destruction shocks as well as endogenous loan liquidation by banks. This setup is consistent with the evidence that exit is much more likely for low-productivity firms and establishments (Foster et al., 2016) and shares a stylized life cycle of firms with Acemoglu et al. (2018) despite several differences: Types differ in productivity and risk, all firms start in the same high state, and the exit rate is endogenous.

There is an infinite mass of potential entrants, but each producer needs one product design. The mass of entrants equals the number of new designs n_t developed by successful start-ups. At the end of period t, there are N_t^h and N_t^ℓ types with high and low productivity:

$$N_t^h = \omega \left(n_t + N_{t-1}^h\right), \quad N_t^\ell = (1-\omega)\left(n_t + N_{t-1}^h\right) + \phi_{t-1} N_{t-1}^\ell. \tag{1}$$

High-productivity firms include n_t new entrants and N_{t-1}^h incumbents, which remain in this state with probability ω. Otherwise, they transition to the low-productivity state. At the end of $t-1$, firm exit shrinks the mass of ℓ-firms by ϕ_{t-1}, reflecting exogenous destruction and endogenous liquidation.

Aggregate output Y_t is produced by $n_t + N_{t-1}^h$ high- as well as by the surviving fraction ϕ_{t-1} of N_{t-1}^ℓ low-productivity firms that are active in period t:

$$Y_t = y^h \left(n_t + N_{t-1}^h\right) + y^\ell \phi_{t-1} N_{t-1}^\ell. \tag{2}$$

Upon entry, each production firm finances equipment investment of one unit of capital with bank credit and the acquisition of a product design with equity. This mirrors the stylized fact that banks mainly finance tangible investment, which can serve as collateral, and abstain from financing intangible capital such as know-how. The bank loan is continued with a time-varying interest rate until the firm exits. In any period, loan rates are predetermined, equal to i_{t-1}^h for h-types and i_{t-1}^ℓ for ℓ-types. Per-period firm profits, which are paid out as dividends to equityholders, equal

$$\pi_t^h = y^h - i_{t-1}^h, \quad \pi_t^\ell = y^\ell - i_{t-1}^\ell. \tag{3}$$

Start-ups: A fixed share $M \in (0,1)$ of household members become start-up entrepreneurs for one period. A start-up conducts R&D to develop R_t new designs. R&D is risky, and a product design successfully matures with probability p. In this case, it is sold at price v_{t+1} to new producers. Aggregate research output of new designs determines firm creation next period and is equal to:

$$n_{t+1} = pR_tM. \tag{4}$$

We assume that start-ups use $\xi(R_t)$ units of the output good to develop R_t new designs. The cost function $\xi(R_t)$ is convex increasing. The start-up may receive an R&D subsidy, which covers a fraction $w_t \in [0,1)$ of its outlays, and incur the net cost $(1-w_t)\xi(R_t)$. Since earnings are realized only next period, the entrepreneur must finance (net) R&D spending out of household savings that would otherwise yield a return r_t (see Section 2.3 below). This mirrors the fact that start-ups are largely financed with the founders' own wealth. Optimal R&D maximizes the entrepreneur's surplus,

$$\max_{R_t} \frac{pv_{t+1}R_t}{1+r_t} - (1-w_t)\xi(R_t) \qquad \Rightarrow \qquad \frac{pv_{t+1}}{1+r_t} = (1-w_t)\xi'(R_t). \tag{5}$$

2.2 Banks

Banks finance equipment investment of producers and extend long-term loans of size one to n_{t+1} entrants. Credit is continued until either the bank restructures or the firm defaults. The loan rate is time-varying such that loans are symmetric in two groups, namely, risk-free loans with interest rate i_t^h to h-firms and risky loans with interest rate i_t^ℓ to ℓ-firms. Measured at the end of period t, the loan volumes equal the mass of entrants and incumbent producers $L_t^h = n_{t+1} + N_t^h$ and $L_t^\ell = N_t^\ell$.[1] The bank is funded with deposits D_t^d and equity E_t, which require returns of i_t and r_t, respectively. In parallel to (1), loans and deposits

[1] n_{t+1} are loans to entrants that first produce in $t+1$ after acquiring a new design, see (2).

follow the laws of motion where S_t^d denotes newly raised deposits:

$$L_t^h = n_{t+1} + \omega L_{t-1}^h, \quad L_t^\ell = (1-\omega) L_{t-1}^h + \phi_{t-1} N_{t-1}^\ell, \quad D_t^d = S_t^d + D_{t-1}^d. \tag{6}$$

Monitoring: Loans to ℓ-firms are risky as, each period, a fraction $1-q$ of them is subject to a destructive shock and defaults. Banks have expertise in monitoring and can continuously assess individual credit risk. Following Inderst and Mueller (2008), we assume that monitoring yields a signal $s' \in (1,\infty)$ that is informative about the true prospects of the borrower next period. The distributions of signals are $G_1(s')$ among successful firms that will experience no destruction shock and $G_2(s')$ among unsuccessful ones that will be hit by such a shock. They satisfy the *monotone likelihood ratio property*, $d[g_1(s')/g_2(s')]/ds' > 0$, such that $G_1(s') \le G_2(s')$ for all $s' > 1$. High signals are more likely among successful firms, while low values are more likely among unsuccessful ones. A high signal indicates 'good news'. After observing s', the bank forms a *posterior belief*

$$\bar{q}(s') = \frac{q g_1(s')}{q g_1(s') + (1-q) g_2(s')}. \tag{7}$$

The posterior $\bar{q}(s') \in [0,1]$ is the probability that a particular ℓ-firm will perform well (i.e., experience no shock) next period. Accordingly, $1-\bar{q}(s')$ is the conditional default probability of the firm. Note that the monotone likelihood ratio property implies $\bar{q}'(s') > 0$ and that $\bar{q}(s') = q$ if the signal were uninformative.

As argued by Inderst and Mueller (2008), the signal is 'soft information' that merely reflects the bank's assessment of firm prospects. Soft information cannot be part of an enforceable legal contract. Hence, it is not possible to condition the interest rate i_t^ℓ on the signal. The signal exclusively influences the bank's decision whether to continue the loan.

Liquidation: After receiving the performance signal at the end of period t, the bank may restructure ('liquidate') an ℓ-loan and immediately recover the liquidation value $1-c$ of the underlying asset. Instead of waiting for the borrower's eventual default, the bank limits its own credit loss to the liquidation cost $c < 1-z$. At the same time, the bank withdraws productive capital, forcing the firm to close down.

Specifically, the bank liquidates whenever monitoring yields a poor performance signal below a given cut-off, $s' < s_t$, indicating a high default probability of the borrower, $\bar{q}(s') < \bar{q}(s_t)$. The fraction of liquidated ℓ-loans is:

$$G(s_t) \equiv qG_1(s_t) + (1-q)\,G_2(s_t)\,. \tag{8}$$

Banks can extract liquidation values $(1-c)\,G(s_t)\,L_t^\ell$ in total and reallocate these funds to new lending. However, monitoring is imperfect since the signal does not precisely reveal a borrower's type. Banks make type I/II errors: They continue a fraction $1 - G_2(s_t)$ of the share $1-q$ of loans to firms that will receive a destruction shock because the signal is 'too good', $s' > s_t$. Such loans which are not restructured but will be in default are *non-performing* loans. At the same time, banks erroneously terminate a share $G_1(s_t)$ of the fraction q of performing loans due to a low signal $s' \leq s_t$.

Liquidation determines the survival rate of ℓ-firms as the latter exit if loans are liquidated. The survival rate equals the average success probability of continuing firms:

$$\phi_t = \int_{s_t}^{\infty} \bar{q}(s')\,dG(s') = q\left[1 - G_1(s_t)\right]. \tag{9}$$

Only loans with good performance signals $s' \geq s_t$ are continued. The conditional success probability of each of these firms is $\bar{q}(s')$. Substituting $\bar{q}(s') = qg_1(s')/g(s')$ from (7-8) shows that a firm only succeeds if it neither receives a shock (with prob. q) nor is liquidated (prob. $1 - G_1(s_t)$). Without liquidation, $s_t = 0$, the survival rate would be exogenous, $\phi_t = q$.

Flow of Funds: Interest rates are predetermined. At the end of period t, the bank receives interest income $i_{t-1}^h L_{t-1}^h + \phi_{t-1} i_{t-1}^\ell L_{t-1}^\ell$, collects the residual value of ℓ-loans that were previously not restructured and are in default $(1-q)(1-G_2(s_{t-1}))zL_{t-1}^\ell$, and raises new deposits S_t^d. It also recovers proceeds $(1-c)G(s_t)L_t^\ell$ from restructuring a fraction $G(s_t)$ of ℓ-loans that are outstanding at the end of t; some of these firms were already in the low-productivity state in the previous period, while others just transitioned from the high state. The outflow consists of n_{t+1} new loans, the interest expense on deposits

$i_{t-1}D^d_{t-1}$, and dividends π^b_t.[2] This motivates the flow of funds equation:

$$\begin{aligned} i^h_{t-1}L^h_{t-1} + \phi_{t-1}i^\ell_{t-1}L^\ell_{t-1} + (1-q)[1-G_2(s_{t-1})]zL^\ell_{t-1} + S^d_t + (1-c)G(s_t)L^\ell_t \\ = n_{t+1} + i_{t-1}D^d_{t-1} + \pi^b_t. \end{aligned} \tag{10}$$

In other words, the bank finances new loans with its net interest income, with external funds from depositors and shareholders $S^d_t - \pi^b_t$, and by redirecting existing funds either from newly restructured or previously defaulted loans $(1-c)G(s_t)L^\ell_t + (1-q)(1-G(s_{t-1}))zL^\ell_{t-1}$.

Balance Sheet and Capital Regulation: Equity E_t equals assets minus liabilities. Outstanding loans at the end of period t are $\omega L^h_{t-1} + L^\ell_t$, which accounts for the fact that some borrowers have transitioned from the h- to the ℓ-state. In addition, the bank grants n_{t+1} new loans, while liquidating $G(s_t)L^\ell_t$ loans. Total loans for the next period equal $L_t \equiv L^h_t + [1-G(s_t)]L^\ell_t$, and equity is $E_t = L_t - D^d_t$.

Banks are subject to regulatory capital requirements: Equity has to be at least a fraction e of total assets, $E_t \geq eL_t$. By substituting for E_t, one obtains the regulatory constraint:

$$(1-e)L_t - D^d_t \geq 0, \quad L_t \equiv L^h_t + [1-G(s_t)]L^\ell_t. \tag{11}$$

Bellman Problem: The bank chooses the amount of new loans n_{t+1} and deposits S^d_t as well as the liquidation cut-off s_t at the end of period t to maximize the value of dividends, which follow from the flow equation (10), subject to the regulatory constraint (11). The state variables are L^h_{t-1}, L^ℓ_{t-1}, and D^d_{t-1} governed by the laws of motion in (6). The cut-off s_t is chosen in period t but becomes a state variable in $t+1$ because it influences future earnings via the exit rate. With future bank profits discounted with the return on equity r_{t-1}, the Bellman problem, which is solved step by step in Appendix A.2, is:

$$(1+r_{t-1})V^b(L^h_{t-1}, L^\ell_{t-1}, D^d_{t-1}, s_{t-1}) = \max_{n_{t+1}, S^d_t, s_t} \pi^b_t + V^b(L^h_t, L^\ell_t, D^d_t, s_t) \quad s.t. \quad (11). \tag{12}$$

[2]An equivalent interpretation is that n_{t+1} constitutes a stream of new loans extended throughout next period. Similarly, the bank may receive performance signals and restructure loans only over time during $t+1$. Nevertheless, the net outflow $n_{t+1} - (1-c)G(s_t)L^\ell_t$ has to be covered by funds available at the end of period t.

2.3 Mutual Fund

Producers and banks are partly financed with equity that is provided by households. We assume that households (with the exception of start-up entrepreneurs) do not directly hold equity of firms or banks. Instead, they invest in a professionally managed and diversified mutual fund and demand a return r_{t-1}. The fund invests $v_t n_t$ in new firm equity. In period t, it collects total firm and bank dividends:

$$\pi_t^e = \pi_t^h (n_t + N_{t-1}^h) + \pi_t^\ell \phi_{t-1} N_{t-1}^\ell - v_t n_t + \pi_t^b. \tag{13}$$

The fund optimally chooses new firm equity n_t subject to the laws of motion in (1). Note that $\pi_t^b < 0$ represents an equity injection. The mutual fund solves the Bellman problem:

$$(1 + r_{t-1}) \, V(N_{t-1}^h, N_{t-1}^\ell) = \max_{n_t} \; \pi_t^e + V(N_t^h, N_t^\ell). \tag{14}$$

The solution is in Appendix A.1. Due to free entry into the production sector, the fund is willing to pay a price for a new design v equal to the present value of expected profits over the firm life cycle. The recursive solution in (A.1) is most transparent in a steady state with $\lambda^h \equiv dV/dN^h$ and $\lambda^\ell \equiv dV/dN^\ell$ denoting the shadow values of firm ownership,

$$v = (1 + r) \, \lambda^h, \quad \lambda^h = \frac{\pi^h + (1 - \omega) \, \lambda^\ell}{1 + r - \omega}, \quad \lambda^\ell = \frac{\phi \pi^\ell}{1 + r - \phi}. \tag{15}$$

2.4 Households

Households derive utility from consumption C_t and deposits D_{t-1}. They value deposits as safe and liquid assets, which gives rise to a *convenience yield* on deposits as in Van den Heuvel (2008) and Begenau (2020). In the subsequent analysis, we use separable preferences where $\bar{C}_t$ is a quasi-linear index of consumption and liquidity services:

$$u\left(C_t, D_{t-1}\right) = \frac{\bar{C}_t^{1-1/\sigma} - 1}{1 - 1/\sigma}, \quad \bar{C}_t \equiv C_t + \psi^{1/\eta} \frac{D_{t-1}^{1-1/\eta}}{1 - 1/\eta}. \tag{16}$$

The household portfolio consists of deposits D_t and equity A_t with returns i_{t-1} and r_{t-1} on past investments. Households also earn per-period net income $\bar{\pi}_t = v_t n_t - T_t$, equal to the earnings of the last generation of start-up entrepreneurs $v_t n_t = v_t p R_{t-1} M$ net of a lump-sum tax that covers the fiscal cost of R&D subsidies. In addition, household entrepreneurs pre-finance net R&D spending $(1 - w_t)\xi_t M$ of new start-ups which generate earnings next period. Denoting new deposits by S_t, the budget constraint is

$$A_t = (1 + r_{t-1}) A_{t-1} + \bar{\pi}_t - (1 - w_t)\xi_t M - S_t - C_t, \quad D_t = (1 + i_{t-1}) D_{t-1} + S_t. \tag{17}$$

The optimality conditions are derived in Appendix A.1:

$$\bar{C}_t^{-1/\sigma} = \beta (1 + r_t) \cdot \bar{C}_{t+1}^{-1/\sigma}, \quad \left[\frac{\psi}{D_{t-1}}\right]^{1/\eta} = r_t - i_t. \tag{18}$$

The interest rate spread $r_t - i_t$ is equal to the convenience yield on deposits $(\psi/D_{t-1})^{1/\eta}$, which enables banks to raise deposits at a rate strictly below the return on equity. Due to separability, optimal deposits are independent of consumption and determined only by the interest rate spread.[3] The convenience yield is diminishing in deposit holdings, reflecting the diminishing marginal liquidity benefit. Accordingly, the deposit rate needs to rise relative to the return on equity if the banking sector is demanding more deposits.

2.5 Markets

In competitive equilibrium, all agents choose optimal plans, budget constraints hold with equality, markets clear, and the tax revenue covers the outlays of R&D subsidies. Equilibrium in output, deposit, and equity markets requires:

$$Y_t = C_t + I_t + \xi_t M, \quad D_t = D_t^d, \quad A_t = V_{t+1}. \tag{19}$$

The output good is used for consumption, net investment, and (gross) R&D spending. Net investment, in turn, equals the equipment investment of n_{t+1} entrants minus reallocated

[3]This ensures that the comparative statics remain tractable. We show in the Online Appendix that the simulation results are robust to alternative preference specifications in which deposit supply directly depends on consumption.

capital goods $(1-c)\,G\,(s_t)\,N_t^\ell$ from liquidation in period t and the residual value of $(1-q)(1-G_2(s_{t-1}))N_{t-1}^\ell$ firms[4] that failed during the previous period:

$$I_t = n_{t+1} - (1-c)\,G\,(s_t)\,N_t^\ell - z\,(1-q)\,(1-G_2\,(s_{t-1}))\,N_{t-1}^\ell. \tag{20}$$

Equity market clearing requires that the end-of-period equity investments of households A_t equal the value of the mutual fund V_{t+1}. Appendix A.1 documents Walras' Law.

3 Theoretical Analysis

3.1 Bank Credit Reallocation

Banks optimally choose new loans and deposits as well as loan liquidation to maximize dividends subject to capital requirements (12). Appendix A.2 derives the detailed solution. Since equity is more expensive than deposits, the regulatory constraint binds. Accordingly, deposits and equity are equal to $D_t^d = (1-e)\,L_t$ and $E_t = eL_t$ and $D_t^d = (1-e)\,L_t$, with continued loans given by $L_t = L_t^h + [1-G(s_t)]L_t^\ell$.

Liquidation: The bank liquidates a loan if the performance signal s' indicates too low a success probability next period, $\bar{q}\,(s') < \bar{q}\,(s_t)$. The monotone likelihood ratio property implies $\bar{q}'\,(s') > 0$ and determines a unique optimal cut-off s_t, which is characterized by the first-order condition:

$$1 + \bar{r}_t - (1+r_t)c = \bar{q}(s_t)\tilde{\lambda}_{t+1}^{b,\ell} + [1-\bar{q}(s_t)]z, \quad \bar{r}_t \equiv (1-e)\,i_t + er_t. \tag{21}$$

We denote by $\bar{r}_t$ the weighted borrowing cost of a bank at the regulatory minimum. The optimal cut-off trades off the bank's marginal benefit and cost: The left-hand side represents the marginal benefit consisting of the immediate release of the liquidation value $1-c$ that can be used for new lending and allows the bank to economize on external borrowing costs. The right-hand side is the marginal cost in terms of forgone earnings: The marginal

[4] When a firm is liquidated or is in default, banks seize the assets and sell them on the market for capital goods at a discount $1-c$ and z respectively. Gross investment n_{t+1} consists of newly produced equipment I_t plus used and refurbished capital goods that were previously produced.

borrower would have survived the period with probability $\bar{q}(s_t)$, creating a shadow value $\tilde{\lambda}^{b,\ell}_{t+1}$ for the bank; the latter is defined and explained in (A.9) and represents the shadow value of a loan to an ℓ-firm that survives the period. The borrower would have defaulted with the complementary probability, in which case the bank would have appropriated z.

Loan Rates and Shadow Values: Competitive banks earn zero profits. Hence, the bank's shadow value of a newly extended loan is equal to its (gross) borrowing cost, $(1 + r_t)\lambda^{b,h}_{t+1} = 1 + \bar{r}_t$. This value encompasses the present value of both the interest income in the current period i^h_t as well as the stream of future earnings depending on whether the borrower remains in the high-productivity state at the end of the period (probability $1-\omega$) or transitions to the low-productivity state (prob. ω). In principle, zero profits are thus consistent with different interest rate profiles for h- and ℓ-loans. We henceforth focus on a competitive equilibrium in which banks break even on both types of loans separately. It follows from equation (A.11) that the interest rate on h-loans equals the weighted borrowing cost, $i^h_t = \bar{r}_t$, and that the shadow value of a (successful) ℓ-loan equals the gross interest rate, $\tilde{\lambda}^{b,\ell}_{t+1} = 1 + i^\ell_t$. To determine the latter, Appendix A.2 derives a zero profit condition for ℓ-loans:

$$1 + \bar{r}_t = [1 + \bar{r}_t - (1 + r_t)c]G(s_t) + \phi_t\tilde{\lambda}^{b,\ell}_{t+1} + (1 - q)[1 - G_2(s_t)]z. \tag{22}$$

The borrowing cost $1+\bar{r}_t$ must equal the expected earnings on an ℓ-loan: With probability $G(s_t)$, the bank restructures this loan and can lower its external borrowing cost by $1 + \bar{r}_t - (1 + r_t)c$. With probability ϕ_t, loan is continued and successful with shadow value $\tilde{\lambda}^{b,\ell}_{t+1}$, while it is continued but ends up in default with the residual value z otherwise. By following the steps in (A.12)-(A.13), one eventually obtains the competitive shadow value and interest rate for ℓ-loans:

$$\tilde{\lambda}^{b,\ell}_{t+1} = 1 + i^\ell_t = \frac{1 + \bar{r}_t - (1 - \varphi(s_t))\, z}{\varphi(s_t)}, \quad \varphi(s_t) \equiv \phi_t + \bar{q}(s_t)\, G(s_t)\,. \tag{23}$$

They both equal the bank's weighted borrowing cost net of the residual value z in the event of default and are adjusted by a risk premium $1/\varphi > 1$. Without liquidation, $\varphi(1) =$

$\phi(1) = q$, the loan rate would collapse to $1 + i_t^\ell = (1 + \bar{r}_t - (1-q)z)/q$. Restructuring loans with poor prospects reduces average credit risk and warrants a smaller risk premium, $\varphi'(s_t) = \bar{q}'(s_t)G(s_t) > 0$.

Restructuring and Loan Quality: We combine (21) and (23) to express the optimal liquidation cut-off s_t in competitive equilibrium by:

$$\bar{q}(s_t) = \left[1 - \frac{(1+r_t)c}{1 - z + \bar{r}_t}\right]\varphi(s_t). \tag{24}$$

Appendix A.2 verifies subsequent to (A.13) that a unique interior solution s_t exists. Note that the bank's liquidation decision only depends on the interest rates in the current period. The reason is that competition drives the expected future profits on ℓ-loans to zero such that forgone shadow value of a liquidated loan is simply $1 + i_t^\ell$. The latter, in turn, reflects the current borrowing cost plus a risk premium.

Given the optimal cut-off in (24), a bank liquidates a share $G(s_t)$ of all L_t^ℓ risky loans. However, the performance signal is noisy, and the bank continues some loans that will receive a destruction shock (type II error). Such *non-performing loans*, which are not restructured and will end up in default, account for a share $\int_{s_t}^{\infty}(1 - \bar{q}(s'))dG(s') = (1-q)(1 - G_2(s_t))$ of all ℓ-loans. One can measure loan quality by the non-performing loans (NPL) ratio, which expresses the non-performing loans relative to all continued loans:

$$NPL_{t+1} = \frac{(1-q)[1 - G_2(s_t)]L_t^\ell}{L_t}. \tag{25}$$

Determinants of Credit Reallocation: The bank's optimal liquidation cut-off s_t is the key statistic that pins down the volume of reallocated credit and the exit rate of low-productivity firms. To study the sensitivities of loan restructuring, we differentiate this cut-off in steady state and focus on the liquidation cost c and the deposit rate i as the main determinants. We abstract from the cost of equity r because it is fixed by the discount rate in steady state and remains constant. The differential of the liquidation cut-off (24) is[5]

$$ds = \sigma\chi \cdot di - \sigma \cdot dc, \tag{26}$$

with positive coefficients

$$\sigma \equiv \frac{\varphi(s)^2}{\bar{q}'(s)\phi(s)} \frac{1+r}{1-z+\bar{r}}, \quad \chi \equiv \frac{(1-e)c}{1-z+\bar{r}}.$$

Note $\chi < 1$ and recall $\bar{q}'(s) > 0$ due to the monotone likelihood ratio property. Banks choose a lower cut-off s and restructure fewer loans whenever liquidation entails a high cost c. In this case, the bank incurs a larger loss and releases less capital for new lending.

The liquidation cut-off also depends on the endogenous deposit rate i. Banks optimally restructure a larger fraction of loans if external deposits are more expensive. Reallocating outstanding credit is more attractive whenever deposits become scarce and the interest rate rises. This effect mirrors a similar mechanism in the seminal model by Melitz (2003), in which a rising factor price (the wage) induces labor reallocation.

Loan restructuring affects firm exit: A higher liquidation cut-off reduces the survival rate of low-productivity firms, $d\phi = -qg_1(s) \cdot ds$. In addition, it unambiguously improves the quality of banks' loan portfolios by reducing the share of loans which will be in default but are not prematurely liquidated. The non-performing loans ratio in steady state[6] unambiguously decreases in the liquidation cut-off:

$$dNPL = -\frac{NPLqg_1(s)\omega/(1-\omega) + (1-NPL)(1-q)g_2(s)}{(1-\phi)/(1-\omega) + 1 - G(s)} \cdot ds. \tag{27}$$

3.2 Firm Turnover and Production

We consider two interventions at the firm entry and exit margin: A change in the liquidation cost c and the introduction of an R&D subsidy w aimed at fostering business creation. The former reflects the quality of a country's insolvency framework and determines the efficiency

[5]Note $\left[\bar{q}' - \frac{\bar{q}}{\varphi}\varphi'\right] \cdot ds = -\frac{1+r}{1-z+\bar{r}}\varphi \cdot dc$. Using $\varphi' = \bar{q}'G$ together with $\varphi - \bar{q}G = \phi$ gives the result.

[6]The steady-state NPL ratio $NPL = \frac{(1-q)[1-G_2(s)]}{(1-\phi)/(1-\omega)+1-G(s)}$ results from substituting the stationary ratio $N^\ell/(n+N^h) = (1-\omega)/(1-\phi)$ from (1) into (25).

of loan restructuring. Empirical research not only documents large cross-country variation in insolvency regimes, it also suggests that a weak insolvency laws hamper reallocation by encouraging 'zombie lending' (Andrews and Petroulakis, 2019), and may depress TFP growth in dynamic industries (Adalet McGowan et al., 2017).

We proceed in two steps: First, we analyze the partial equilibrium changes of firm dynamics and production, keeping the deposit rate constant. In a second step, we show how the deposit rate adjusts to establish equilibrium and how this feeds back on reallocation. Without loss of generality, we simplify the analysis by evaluating derivatives at a residual value of $z = 0$ and by setting the R&D subsidy to $w = 0$ at the outset. Our scenario considers the introduction of a small subsidy. Empirically, the NPL ratio stated in (25) is low.[7] This allows us to focus on a low share of restructured loans $G(s)$ such that φ and ϕ are close to q. We denote absolute and relative changes by dx and $\hat{x} \equiv dx/x$ and use short-hand notations $G \equiv G(s)$ and $\xi \equiv \xi(R)$.

3.2.1 Partial Equilibrium

By restructuring non-performing loans, banks accelerate firm exit. Their liquidation decision depends on the liquidation cost and the deposit rate (see Section 3.1). Business creation, in turn, results from R&D and is driven by the present value of future profits.

Firm Profits: By (15), the design price corresponds to the present value of firm profits and is equal to $v = (1+r)\left[\pi^h + (1-\omega)\,\phi\pi^\ell/(1+r-\phi)\right]/(1+r-\omega)$ in steady state. Variations in the design price reflect changes in the survival rate ϕ, which determines the expected lifetime of ℓ-firms, and in the loan rates i^h and i^ℓ, which pin down per-period profits π^h and π^ℓ. As shown in (A.13) and (A.14) of Appendix A.2, one can trace back all these changes to variations in the endogenous deposit rate i and the liquidation cut-off s

$$\hat{v} = -\zeta_{vi} \cdot di - \zeta_{vs} \cdot ds. \tag{28}$$

[7]The liquidation cut-off must thus be relatively small, which results in a small share $G(s)$ of restructured loans, even though many unsuccessful firms receive low signals so that $G_2(s)$ is high. Both facts are consistent with a low NPL ratio.

with coefficients defined as

$$\zeta_{vi} \equiv (1-e) \frac{1+\frac{1-\omega}{1+r-\phi}\frac{\phi}{\varphi}}{(1+r-\omega)\,\lambda^h}, \quad \zeta_{vs} \equiv (1-\omega) \frac{\pi^\ell \frac{1+r}{1+r-\phi} q g_1 - \phi \frac{1+i^\ell}{\varphi} \bar{q}' G}{(1+r-\phi)\,(1+r-\omega)\,\lambda^h}.$$

By raising the borrowing costs, a higher deposit rate erodes profits of firms in both states and lowers the present value. The coefficient ζ_{vi} is unambiguously positive. In contrast, the effect of liquidation ζ_{vs} is a priori ambiguous: More aggressive liquidation directly reduces the survival rate ϕ and shortens expected firm lifetime. This effect, captured by the first term in the numerator of ζ_{vs}, reduces the design price. However, restructuring the loan portfolio by eliminating the weakest loans reduces average credit risk and warrants a smaller risk premium on the continued loans, see (23). This positive effect, represented by the second term in the numerator, is proportional to the share of liquidated loans $G\,(s)$ that is assumed to be rather small. Loan liquidation decreases the design price.

Firm Creation: The mass of entrants $n = pRM$ increases one by one with R&D intensity R. The latter depends on the design price v and on the R&D subsidy w: Differentiating the optimality condition (5) gives $\hat{R} = \mu(\hat{v} + dw)$, where $\mu \equiv \xi' / \left(R\xi''\right)$ measures the price elasticity of R&D. Without loss of generality and in line with our subsequent quantitative analysis, we focus on $\mu = 1$. Substituting (28) for $\hat{v}$ gives

$$\hat{n} = \hat{R} = -\zeta_{vi} \cdot di - \zeta_{vs} \cdot ds + dw. \tag{29}$$

A higher deposit rate inflates borrowing costs of banks. The latter raise the lending rate which, in turn, erodes firm profits. The resulting decline in the design price reduces R&D and firm entry. More frequent liquidation also discourages business creation as the design price falls due to the shorter expected firm lifetime as discussed earlier. A subsidy, in contrast, stimulates firm creation by lowering the R&D cost by $\xi \cdot dw$.

Production: Aggregate output depends on the number and composition of firms. Given $N^h = \omega n/(1-\omega)$ and $N^\ell = n/(1-\phi)$ in steady state, output in (2) collapses to $Y =$

$\left[y^h/(1-\omega)+\phi y^\ell/(1-\phi)\right] n$. It changes by:

$$\hat{Y} = \hat{n} - \frac{y^\ell N^\ell}{Y}\frac{qg_1}{1-\phi}\cdot ds = -\zeta_{vi}\cdot di - \tilde{\zeta}_{ys}\cdot ds + dw. \tag{30}$$

The second equality uses (29) as well as $\tilde{\zeta}_{ys} \equiv \zeta_{vs} + (y^\ell N^\ell/Y)qg_1/(1-\phi)$. Output expands with entry, which proportionately raises the number of both types of firms. A higher deposit rate lowers aggregate output as the reduced value of new firms discourages firm creation by ζ_{vi}. Increased loan restructuring lowers output in two ways that constitute the total effect $\tilde{\zeta}_{ys}$ in partial equilibrium: First, it discourages firm creation by reducing expected firm lifetime. Second, it magnifies the type-I error of forcing exit of ℓ-firms without a destruction shock that would still contribute to production. Finally, the R&D subsidy boosts production through higher firm creation.

3.2.2 General Equilibrium

To establish equilibrium, the deposit interest rate i must adjust to clear the deposit market, $D^d = D$. Demand of the banking sector results from the balance sheet constraint and decreases in the deposit rate. Households' portfolio allocation determines supply, which rises with the deposit rate relative to the return on equity. Figure 1 illustrates how a decrease in the liquidation cost c affects deposit market equilibrium.

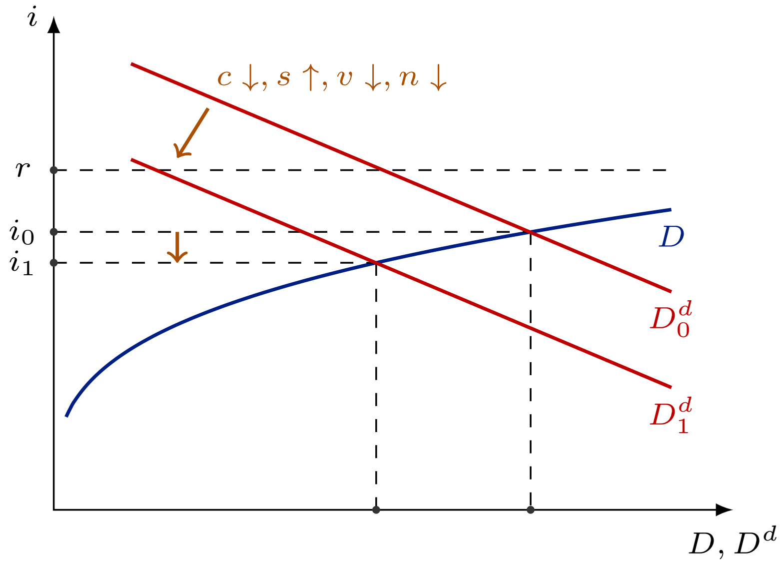

Figure 1: *Deposit Market Equilibrium*

Deposit Demand: Total bank deposits $D^d = (1-e)\,L$ are proportional to loans, $L = L^h + [1-G(s)]\,L^\ell = n + N^h + [1-G(s)]\,N^\ell$. Noting the steady-state values $n + N^h = n/(1-\omega)$ and $N^\ell = n/(1-\phi)$, one observes that the loan volume responds to changes in firm creation and loan restructuring as follows:

$$\hat{L} = \hat{n} - \left[g + \frac{(1-G)\,qg_1}{1-\phi}\right] \frac{N^\ell}{L} \cdot ds. \tag{31}$$

Investment of additional entrants increases lending by $\hat{n}$, while restructuring lowers the loan volume by directly reducing the share of continued loans and by lowering the mass of ℓ-firms. Substituting (26) for ds and (29) for $\hat{n}$, collecting terms and noting $\hat{D}^d = \hat{L}$ yields the changes in deposit demand,

$$\hat{D}^d = -\delta_{di} \cdot di + \delta_{dc} \cdot dc + dw, \tag{32}$$

where both coefficients are positive,

$$\delta_{di} \equiv \zeta_{vi} + \sigma\chi \left[\zeta_{vs} + \left(g + \frac{(1-G)\,qg_1}{1-\phi}\right) \frac{N^\ell}{L}\right], \quad \delta_{dc} \equiv \sigma \left[\zeta_{vs} + \left(g + \frac{(1-G)\,qg_1}{1-\phi}\right) \frac{N^\ell}{L}\right].$$

A rising deposit rate i inflates banks' borrowing costs, which are passed onto all borrowers via higher loan rates. The latter impair firm value v, thereby discouraging business creation. The smaller loan volume, in turn, shrinks deposit demand of banks. A higher loan liquidation cost c weakens banks' incentives to restructure loans, see (26). This raises their deposit demand for two reasons: First, banks recover substantial funds when restructuring their portfolios, which they use for new lending. Reallocating fewer existing funds increases banks' reliance on external deposits, leading to a larger demand. Second, the reduced liquidation rate expands the loan volume to ℓ-firms as discussed in (31). Introducing an R&D subsidy raises deposit demand as banks expand lending to fund additional entrants.

Deposit Supply: The availability of deposits represents the key resource constraint of the economy. Households choose deposits according to (18) such that the convenience yield matches the interest rate spread $r - i$. The steady-state return on equity equals the discount rate on account of the Euler equation, making r exogenous in the long run. Hence, the spread only narrows if the deposit rate i rises. With separable preferences, marginal utility of liquidity services exclusively depends on deposit holdings. Inverting (18) gives an upward-sloping deposit supply schedule, $D = \psi/(r - i)^\eta$, which changes according to:

$$\hat{D} = \frac{\eta}{r - i} \cdot di. \tag{33}$$

The parameter η governs the interest rate elasticity of deposits.

Interest Rate Effect: The equilibrium interest rate clears the deposit market. By equating (32) and (33), one obtains the interest rate effects:

$$di = \varepsilon_{ic} \cdot dc + \varepsilon_{iw} \cdot dw, \quad \varepsilon_{ic} \equiv \frac{\delta_{dc}}{\eta/(r - i) + \delta_{di}}, \quad \varepsilon_{iw} \equiv \frac{1}{\eta/(r - i) + \delta_{di}}. \tag{34}$$

A higher liquidation cost raises the equilibrium deposit rate. By reducing banks' capacity to redirect existing credit, it renders banks more dependent on external funds. This tightens the economy's resource constraint originating from scarce deposits, leading to a higher interest rate. The R&D subsidy has a comparable effect because the inflow of more entrants, which need to finance investment, ultimately boosts deposit demand.

These results are reminiscent of Begenau (2020) who emphasizes a similar equilibrium effect when studying the impact of tighter capital requirements on bank lending. She argues that the induced decrease in the deposit demand of the banking sector causes a quantitatively strong decline in the deposit rate. In the same vein, our result connects to existing research on 'zombie lending' that emphasizes congestion in factor and product markets that crowds out investment and employment growth of healthy firms (Caballero et al., 2008). In our model, reallocating existing loans mitigates congestion in deposit markets as banks eliminate weak firms, which keeps the interest rate low.

The interest rate response's magnitude ε_{ic} and ε_{iw} depends on the elasticity of deposits η. It is large whenever the supply of deposits is relatively inelastic. Specifically, the interest rate is constant and the effect disappears if deposits are perfectly elastic, $\lim_{\eta\to\infty} \varepsilon_{ic} = \lim_{\eta\to\infty} \varepsilon_{iw} = 0$. If they are completely inelastic, they converge to positive upper bounds

$\lim_{\eta\to 0}\varepsilon_{ic} = \delta_{dc}/\delta_{di} = 1/(\chi + \zeta_{vi}/\delta_{dc})$ and $\lim_{\eta\to 0}\varepsilon_{iw} = 1/\delta_{di}$, respectively. We conclude $\varepsilon_{ic} < 1/\chi$ and $\varepsilon_{iw} \leq 1/\delta_{di}$ for all values of η.

Net Effects: The interest rate response can reinforce or offset the direct or partial equilibrium effects of other shocks. This is most obvious with the sensitivities of the optimal *liquidation cut-off* s in (26). Substituting (34) gives the net effects:

$$ds = -\sigma(1 - \chi\varepsilon_{ic}) \cdot dc + \sigma\chi\varepsilon_{iw} \cdot dw. \tag{35}$$

The increase in the equilibrium interest rate dampens the direct effect of a higher liquidation cost in proportion to $\chi\varepsilon_{ic}$. The positive interest rate effect (coefficient ε_{ic}) induces banks to shift from deposit funding to more credit reallocation again ($\sigma\chi$). Noting the upper bound $\varepsilon_{ic} < 1/\chi$, the effect of the liquidation cost on loan restructuring remains unambiguously negative, but it is weaker in general than in partial equilibrium.

Unlike liquidation costs, the R&D subsidy has no direct effect on loan restructuring and, more generally, on firm exit. However, it leads to a higher equilibrium interest rate. As a result, reallocating outstanding loans rather than refinancing them with deposits becomes more attractive. Through this mechanism in general equilibrium, a policy intervention at the firm creation margin influences firm exit as well.

The net effects on *firm creation* are a priori ambiguous as the interest rate responses to liquidation cost and R&D subsidy run counter to the partial equilibrium effect in (29). By substituting (34) and (35) for di and ds, one obtains:

$$\hat{n} = -\left[\varepsilon_{ic}\zeta_{vi} - \sigma(1 - \chi\varepsilon_{ic})\zeta_{vs}\right] \cdot dc + \left[1 - \varepsilon_{iw}(\zeta_{vi} + \sigma\chi\zeta_{vs})\right] \cdot dw. \tag{36}$$

The countervailing interest rate and liquidation effects of the liquidation cost are reflected by the terms in square brackets: On the one hand, it raises the equilibrium deposit rate in proportion to ε_{ic}, which slows down entry on account of higher borrowing costs of firms in both states. On the other hand, a higher liquidation cost induces banks to restructure fewer loans although the rising interest rate dampens this effect. This fosters business creation due to the longer firm lifetime in the low-productivity state.

Which of the two effects prevails depends on the interest rate elasticity of deposits η: Whenever the latter are very elastic, the interest rate response ε_{ic} is small such that a higher liquidation cost increases firm entry similar to the partial equilibrium response $\sigma\zeta_{vs}$. With less elastic deposits, however, the countervailing interest rate effect becomes stronger as the larger demand of the banking sector raises the equilibrium deposit rate. The latter may dominate as soon as deposits are supplied rather inelastically. To see this, consider completely inelastic deposits, $\eta \to 0$, which imply $\lim_{\eta\to 0} \varepsilon_{ic} = \delta_{dc}/\delta_{di}$. The expression in square brackets collapses to $(\sigma\zeta_{vi}/\delta_{di})\,[g + (1-G)\,qg_1/(1-\phi)]\,N^{\ell}/L > 0$.

Introducing an R&D subsidy directly fosters firm creation, see (29). Yet the rising interest rate depresses firm value and dampens the effect. While the subsidy is less effective in stimulating business creation in general than in partial equilibrium, the net effect remains unambiguously positive. To see this, combine $\zeta_{vi} + \sigma\chi\zeta_{vs} < \delta_{di}$ from the definition following (32) with $\varepsilon_{iw} \le 1/\delta_{di}$, and note that the expression in square bracket is positive.

The net changes in *aggregate output* follow from substituting (35) and (36) into (30):

$$\hat{Y} = \Big[\sigma(1-\chi\varepsilon_{ic})\tilde{\zeta}_{ys} - \varepsilon_{ic}\zeta_{vi}\Big]\cdot dc + \Big[1 - \varepsilon_{iw}(\zeta_{vi} + \sigma\chi\tilde{\zeta}_{ys})\Big]\cdot dw. \tag{37}$$

The output effects in general equilibrium largely mirror the entry effects in (36), with one exception: Any induced increase in loan restructuring s has a stronger negative impact on production compared to entry, $\tilde{\zeta}_{ys} > \zeta_{vs}$. Liquidating additional loans not only reduces the mass of producers by discouraging firm creation, but it also magnifies the type-I error in banks' liquidation decisions such that more firms which would still contribute to production are closed down. This first-order liquidation effect is positive in case of higher liquidation cost as the latter reduces loan restructuring, while the reverse is true for the R&D subsidy. On net, a higher liquidation cost may only reduce output if deposits are so inelastic that the entry response in (36) is both negative and sizable.

Policy Complementarities: The R&D subsidy has a weaker effect on firm creation and production in general than in partial equilibrium. The induced increase in the equilibrium deposit rate, which is particularly strong if deposits are inelastic, crowds out some of the new investment. Policymakers may combine this subsidy with measures that facilitate exit of unproductive firms (e.g., reform of insolvency laws). This reduces demand for deposits and helps avoid a crowding out.

Specifically, we consider the introduction of an R&D subsidy together with a simultaneous reduction in the liquidation cost by $dc = -(\varepsilon_{iw}/\varepsilon_{ic}) \cdot dw$. Given (34), this keeps the equilibrium deposit rate constant and neutralizes the general equilibrium effect. Using $di = 0$ in (26) and (29) yields the sensitivities of firm creation[8] to a combined policy:

$$\hat{n} = -\left[1 - \frac{\varepsilon_{iw}}{\varepsilon_{ic}}\sigma\zeta_{vs}\right] \cdot dw. \tag{38}$$

The response mirrors the partial equilibrium effects: On the one hand, the subsidy lowers the R&D costs of start-ups, thereby stimulating firm entry. On the other hand, the lower liquidation cost induces banks to restructure additional loans in proportion to $(\varepsilon_{iw}/\varepsilon_{ic})\sigma$, which depresses the design price v on account of a shorter expected firm lifetime in the low-productivity state, thereby weakening R&D incentives. Noting $\varepsilon_{iw}/\varepsilon_{ic} = 1/\delta_{dc}$ and $\sigma\zeta_{vs} < \delta_{dc}$, the net effect is unambiguously positive, however.

To evaluate whether such a combined approach is more effective in stimulating firm creation than a stand-alone introduction of an R&D subsidy, we compare (38) to the subsidy's net effect $1 - \varepsilon_{iw}(\zeta_{vi} + \sigma\chi\zeta_{ys})$ in general equilibrium (36). After some substitutions, one observes that the combined policy has a stronger effect as long as:

$$\frac{\eta}{r-i} < \frac{\zeta_{vi}}{\zeta_{vs}}\left[g + \frac{(1-G)\,qg_1}{1-\phi}\right]\frac{N^{\ell}}{L}. \tag{39}$$

The interest rate elasticity of deposits must be sufficiently small. In this case, the countervailing interest rate effect that renders the subsidy less effective is particularly strong. Avoiding the latter boosts firm value and outweighs the negative effect of a shorter expected lifetime caused by more loan liquidation. As a result, complementing the R&D subsidy with more efficient firm exit offers larger gains at the firm creation margin whenever deposits are inelastic and the crowding-out via a higher interest rate is strong.

[8] Along the same lines, one can also derive the net effects of aggregate output Y to such a policy as well as a condition for the combined approach to be more effective in stimulating production.

3.3 Aggregate Productivity

In this framework, aggregate productivity depends on the composition of production firms, which are of two types with different output levels, $y^h > y^\ell$. We define the share of high-productivity firms active in period t as follows:

$$\mu_t^h \equiv \frac{n_t + N_{t-1}^h}{n_t + N_{t-1}^h + N_{t-1}^\ell}. \tag{40}$$

Productivity measures: In our model, TFP and (expected) firm output coincide and equal y^h and $\phi_{t-1} y^\ell$, respectively. This accounts for the fact that only a share ϕ_{t-1} of ℓ-firms succeeds in producing output because some are either closed down by banks or fail exogenously. We measure aggregate TFP by *average output per firm*,

$$A_t^f \equiv \frac{Y_t}{n_t + N_{t-1}^h + N_{t-1}^\ell} = \mu_t^h y^h + (1 - \mu_t^h)\phi_{t-1} y^\ell. \tag{41}$$

This measure, however, ignores that loan restructuring releases capital, which is reallocated to new firms. This allows for smaller net investment because some units of equipment are re-used by other firms. To account for reallocation, we define the net capital stock $K_t \equiv n_t + N_{t-1}^h + [1 - (1-c)G(s_{t-1})]N_{t-1}^\ell$: Each of firm uses one unit of capital; from N_{t-1}^ℓ ℓ-firms at the end of $t-1$, a fraction $G(s_{t-1})$ is liquidated and banks recover a share $1-c$ per firm, giving total proceeds of $(1-c)G(s_{t-1})N_{t-1}^\ell$. They are acquired by entrants and reduce net equipment investment to $n_t - (1-c)G(s_{t-1})N_{t-1}^\ell$. It represents the capital stock financed out of household savings.

We relate output to the net capital stock and define *aggregate capital productivity*:

$$A_t^k \equiv \frac{Y_t}{K_t} = \frac{A_t^f}{\kappa_t}, \quad \kappa_t \equiv \frac{K_t}{n_t + N_{t-1}^h + N_{t-1}^\ell} = 1 - (1 - \mu_t^h)(1-c)G(s_{t-1}). \tag{42}$$

The second equality expands by the total mass of firms $n_t + N_{t-1}^h + N_{t-1}^\ell$. The term $\kappa_t \in (0,1)$ represents the average net capital per firm. Note $A_t^k \geq A_t^f$.

Comparative Statics: Average firm output (41) is determined by the share of high-productivity firms, which collapses to $\mu^h = (1-\phi)/(1-\omega+1-\phi)$ in steady state, and the survival rate of ℓ-firms ϕ. Taken together, the percentage change in average firm output purely reflects changes in the liquidation cut-off s:

$$\hat{A}^f = \frac{A^f - y^\ell}{A^f}(1-\mu^h)\frac{qg_1}{1-\phi} \cdot ds. \tag{43}$$

Loan restructuring entails (i) a positive *reallocation* effect as exiting ℓ-firms are replaced by more productive entrants, which raises the share of h-firms μ^h, and (ii) a negative *liquidation* effect because the survival rate ϕ falls, leading to smaller expected firm output. The former prevails as long as firms are on average more productive than a successful ℓ-firm.

Aggregate capital productivity is also driven by changes in net capital per firm, $\hat{A}^k = \hat{A}^f - \hat{\kappa}$. In steady state, the latter equals $\kappa = 1-(1-\mu^h)(1-c)G(s)$. Appendix A.2 derives the sensitivities to changes in loan restructuring s and the liquidation cost c,

$$\hat{A}^k = -\frac{1-\mu^h}{\kappa}G \cdot dc + \frac{1-\mu^h}{\kappa}\alpha^{k,s} \cdot ds \tag{44}$$

with

$$\alpha^{k,s} \equiv \left[\frac{A^k - y^\ell}{A^k} + (1-c)(1-q)(1-G_2)\right]\frac{qg_1}{1-\phi} + (1-c)(1-q)g_2.$$

A rising liquidation cost c impairs aggregate capital productivity because net capital per firm κ must rise if less capital is released in the liquidation process. The effect of loan restructuring is represented by $\alpha^{k,s}$: In addition to the countervailing reallocation and liquidation effects on average firm output A^f, restructuring boosts aggregate capital productivity by lowering net capital per firm. The net effect is likely positive.

Finally, firm creation n affects neither productivity measure. It scales output, the number of firms, and net capital but does not alter firm composition. This is the reason why the elasticity of deposits, which is key at the firm creation margin, does not directly influence sign or magnitude of the productivity effects.

4 Calibration

We calibrate the model to a deterministic steady state at an annual frequency. Given our emphasis on banks as major financiers of investment, the quantitative analysis is best applied to continental Europe that is especially bank dependent. We set key calibration targets based on data for France (2012-18), one of the largest banking markets in Europe. Appendix A.3 contains the details, robustness checks, and all derivations for our calibration.

For calibration, we consider the firm exit rate and the non-performing loans (NPL) ratio, which both result from banks' liquidation decisions, as well as leverage and productivity (TFP) dispersion in the firm sector. Moreover, we set the discount factor to support the return on equity. The remaining parameters of the model are calibrated to structural data.

Parameter		Steady-state targets		Source
Liquidation cost	$c = 0.301$	Exit rate	$1 - \phi = 0.11$	Eurostat (2012-18)
Pareto shape	$\alpha_2 = 24.58$	NPL ratio	$NPL = 0.03$	EBA (2016-18)
Output ℓ-firms	$y^\ell = 0.0894$	Firm leverage	$v/(1+v) = 0.4$	BACH (2012-18)
Output h-firms	$y^h = 0.13$	TFP dispersion	$IQR = 0.45$	Bartelsman & Wolf (2018)
Discount factor	$\beta = 0.935$	Return equity	$r = 0.07$	Jordà et al. (2019)

Table 1: *Calibration: Implied Parameters*

We assume that the performance signal $s' \in [1, \infty)$ is drawn from a Pareto distribution $G_i(s') = 1 - (s')^{-\alpha_i}$; the shape parameters $\alpha_1 < \alpha_2$ ensure the monotone likelihood ratio property. Our first target is a survival rate of ℓ-firms of $\phi = q[1 - G_1(s)] = qs^{-\alpha_1} = 0.89$. As detailed in Appendix A.3, this is consistent with the annual business exit rate among French non-financial firms of 5.5 percent. We assume that 9 percent of ℓ-firms receive a destruction shock each period, $q = 0.91$, and set the shape parameter $\alpha_1 = 1.25$. Given these values, the liquidation cut-off $s = (q/\phi)^{1/\alpha_1} \approx 1.018$ supports the calibration target.

The Pareto shape parameter α_2, in turn, is set to support a steady-state NPL ratio of three percent. This is broadly consistent with the recent NPL ratios of French banks that range between 2.7 and 3.7 percent according to the European Banking Authority (EBA). This calibration implies that banks liquidate a fraction $G_2(s) = 0.351$ of loans to ℓ-firms hit by a destruction shock and that the total share of restructured loans is $G(s) = 0.052$.

We set the residual value of failed firms to $z = 0.4$; $1 - z = 0.6$ represents the loss given default (LGD), a key parameter for bank regulators. In the Basel accords, the LGD for non-collateralized corporate exposures ranges between 45 and 75 percent. Eventually, we calibrate the liquidation cost c to ensure that the cut-off $s = 1.018$ is indeed optimal for these parameter values. By (24), we find $c = (1 - z + \bar{r})/(1 + r)(1 - \bar{q}/\varphi) = 0.301$. The implied loan recovery value of 70 percent is broadly consistent with empirical estimates (Acharya et al., 2007; Grunert and Weber, 2009).

Parameter		Source
Capital requirements	$e = 0.03$	Leverage ratio (Basel accords)
Residual value	$z = 0.4$	LGD (Basel accords)
Elasticity deposits	$\eta = \{0.3, 1.2\}$	Chiu and Hill (2018)
Patent elasticity	$\mu/(\mu + 1) = 0.5$	Akcigit and Kerr (2018)
IES	$\sigma = 0.5$	Standard

Table 2: *Calibration: Structural Data*

On the firm side, we calibrate output (TFP) levels y^h and y^ℓ to match the firm-level productivity dispersion and leverage. Syverson (2004b) reports an interquartile range (IQR) of establishment-level TFP within U.S. manufacturing industries between 1.34 and 1.56. Hence, the establishment at the 75th percentile of the TFP distribution exhibits between 34 and 56 percent higher TFP than the establishment at the 25th percentile. Syverson (2004a) reports a similar IQR of 1.32 for U.S. ready-mixed concrete plants. For manufacturing firms in France, Bartelsman and Wolf (2018) report estimates of the IQR between 1.27 and 1.69. The model features two groups of firms, namely, h-types with output y^h and ℓ-types with output of either $y^\ell < y^h$ or 0. We assume that both groups are equally large: h-firms constitute the upper and ℓ-firms the lower half of the productivity distribution. Hence, output at the 75th percentile of the output distribution is y^h, and firm output at the 25th percentile is y^ℓ.[9] For calibration, we use an IQR of 1.45 and get that the output of h-firms is 45 percent higher, $y^h = 1.45 \cdot y^\ell$.

While the firm design v is funded with equity, investment of size one is funded with

[9] The production sector exhibits the following (degenerate) distribution of firm output: Since 15% of ℓ-firms, which represent half of all firms, exit with zero output, firm output below the 7.5th percentile (of the entire output distribution) is 0. All other ℓ-firms produce y^ℓ, and output between the 7.5th and the 50th percentile equals y^ℓ. Above the median, output is y^h.

debt. The firm's equity ratio equals $v/(1+v)$. Using information from the BACH database about non-financial firms in France (2012-18), we target an equity ratio of 40 percent, which requires a design price of $v = 2/3$. We match the latter by using firm output y^ℓ.

Eventually, the preference parameter η governs the interest rate elasticity of deposits. Estimates of Chiu and Hill (2018) suggest a rate elasticity between 0.1 and 0.5 in the U.K.; transforming the rate elasticity implies values for η between 0.25 and 1.25. Using U.S. data, Drechsler et al. (2017) estimate a semi-elasticity of deposits of 5.3, corresponding to an elasticity $\eta \approx 0.27$ in our case. We explore a high- and a low-elasticity scenario with elasticity at its upper and lower bound, $\eta = \{0.3, 1.2\}$. Accordingly, the parameter ψ, which represents the liquidity benefit of deposits, is set to match the supply and demand of deposits given an interest rate spread $r - i = 0.05$ separately in each scenario.

5 Quantitative Analysis

This section explores the quantitative effects of bank credit reallocation in three ways: First, we simulate a policy improvement at the firm exit margin, namely, a reduction in the liquidation cost, which renders loan restructuring more efficient. Second, we consider the introduction of an R&D subsidy designed to simulate firm creation and thereby highlight strong policy complementarities at entry and exit margins under inelastic deposits. Third, we compare the initial steady state to two benchmarks in which monitoring (i) is uninformative such that banks refrain from loan restructuring altogether or (ii) perfectly reveals credit risk avoiding any errors in banks' liquidation decisions. This quantifies the discrete effects of credit reallocation as well as imperfect information in monitoring. The results are robust to alternative specifications of the utility function as shown in the Online Appendix.

5.1 Firm Exit: Efficiency of Loan Liquidation

Liquidation costs c determine how much banks recover per restructured loan and influences their liquidation decision. Improved insolvency laws, for example, help reduce this cost allowing banks to release more funds for new lending. We consider a 25 percent reduction of liquidation costs. We lower the long-term value $\bar{c}$ from 0.301 to 0.226 and let the liquidation cost adjust gradually according to $c_t = (1-\rho)\bar{c} + \rho c_{t-1}$ with $\rho = 0.9$.

Figure 2 shows the main outcomes for the low- ($\eta = 0.3$, solid red line) and high-elasticity ($\eta = 1.2$, blue dashed line). A lower liquidation cost induces banks to restructure more loans: The share of liquidated ℓ-loans $G(s)$ increases from 5.2 to 9.8 percent, and the exit rate of ℓ-firms ϕ rises from 11 to 13.3 percent.

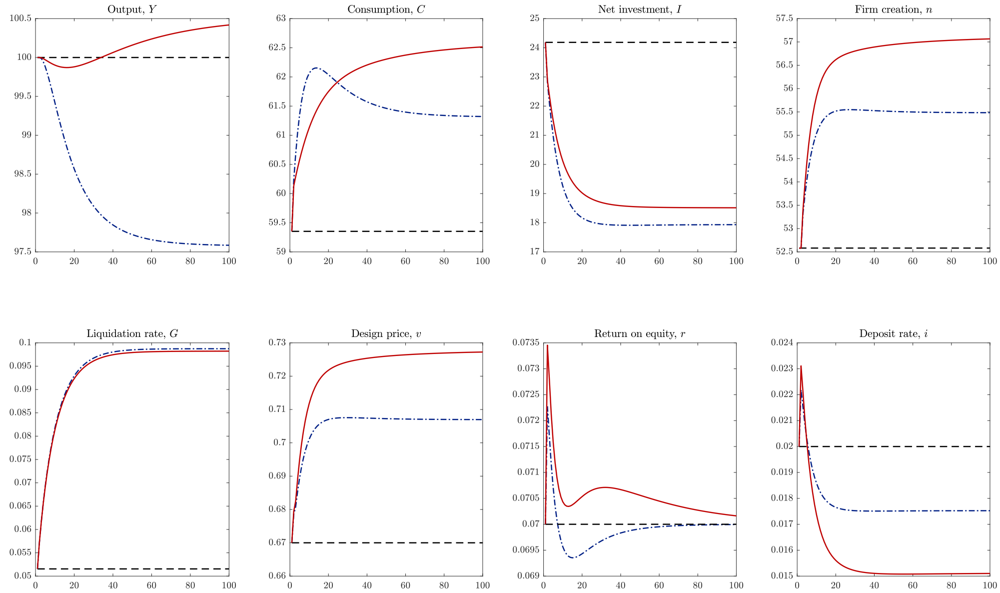

Figure 2: *Simulation results: Liquidation cost*

Higher exit rates lead to a decline in the deposit rate i from 2 to 1.75 in the high- and 1.5 percent in the low-elasticity scenario, respectively. The interest rate effect is roughly twice as large if deposits are inelastic. The lower deposit rate is passed on to borrowers and raises the design price v which, in turn, boosts firm creation n by 5.5 and 8.6 percent.

Changes in aggregate output Y reflect a negative *liquidation effect* as some firms that would have contributed to production are closed down and a positive *entry effect* due to increased firm creation. If deposits are inelastic, the entry effect dominates leading to an increase in long-term output of 0.5 percent. With more elastic deposits, the interest rate declines by less, and the entry response is weaker, resulting in an output loss of 2.4 percent. Net investment I falls by 23 and 26 percent: Both the lower liquidation cost c and the higher liquidation rate $G(s)$ raise the volume of reallocated funds. Hence, consumption C increases by 3.3 percent if deposits are elastic and 5.5 percent if they are inelastic.

Table 3 summarizes the steady-state effects on loan quality and aggregate productivity. These effects follow from the higher liquidation rate and are independent of any entry response; the elasticity of deposits has a negligible impact. Instead of liquidating less than half of loans to firms hit by a destruction shock, banks now terminate more than two thirds. As a result, the non-performing loans ratio falls by 1.35 percentage points.

	ISS	Liquidation Cost -25%	
		$\eta = 0.3$	$\eta = 1.2$
Non-performing loans NPL	3%	1.66%	1.64%
Share h-firms μ^h	50%	54.77%	54.83%
Avg. output/firm A^f	0.105	+1.39%	+1.40%
Net capital/firm κ	0.982	-1.67%	-1.68%
Aggr. capital prod. A^k	0.107	+3.11%	+3.14%

Table 3: *Loan quality and aggregate productivity*

More efficient liquidation also promises permanent aggregate productivity gains. The share of productive h-firms increases by five percentage points. The gains in average output per firm A^f, however, amount to only 1.4 percent because the survival rate of ℓ-firms is smaller. Aggregate capital productivity $A^k = A^f/\kappa$, in contrast, rises by 3.1 percent. The smaller net capital per firm κ due to the higher liquidation value $1 - c$ and the larger liquidation share $G(s)$ reinforces the increase in average firm output.

5.2 Firm Creation: R&D Subsidy

We consider the introduction of an R&D subsidy w that covers five percent of start-up costs $\xi(R_t)$. We postulate that the subsidy is gradually implemented according to $w_t = (1-\rho)\bar{w} + \rho w_{t-1}$ with $\rho = 0.9$ and raise the long-term value $\bar{w}$ from zero to 0.05.

Figure 3 plots the effect for the low- (red, solid line) and high-elasticity (blue, dashed line) scenarios, associated with interest rate increases of different magnitude. The lower net R&D cost of start-ups stimulates firm creation n, which rises by 1.7 percent in the low- and 3.4 percent in the high-elasticity scenario. As a result, aggregate output grows by 1.6 and 3.3 percent, respectively. This creates consumption gains: Despite larger R&D spending and investment, consumption C is between 1.2 and 2.4 percent higher in the long run.

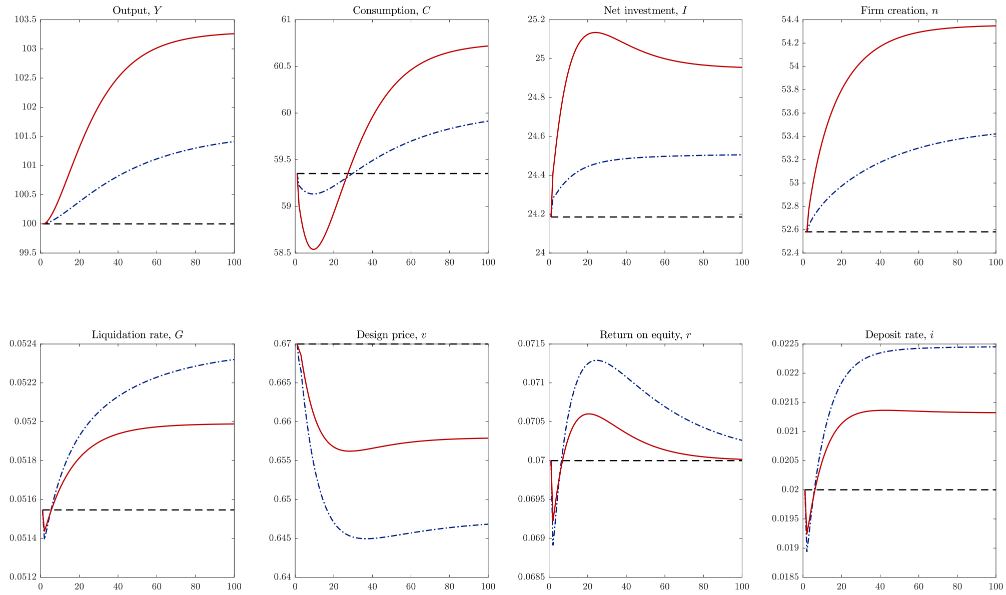

Figure 3: *Simulation results: R&D Subsidy*

The R&D subsidy entails a counteracting interest rate effect: Larger credit demand of producers boosts the deposit demand of the banking sector, leading to a higher equilibrium deposit rate i. The increase is almost twice as large, that is, 0.25 instead of 0.13 percentage points, whenever deposits are inelastic. Due to the higher borrowing costs, firm value v declines by 1.8 to 3.4 percent, leading to a partial crowding-out of investment of high-productivity entrants that is particularly pronounced under inelastic deposits.

Banks do respond to the higher deposit rate by restructuring more non-performing loans, see Section 3.1. This accelerates exit of unproductive firms, eases funding pressure and alleviates the crowding-out. The effect, however, is quantitatively small as the share of liquidated loans $G(s)$ only increases by 0.09 percentage points.

With inelastic deposits, introducing an R&D subsidy offers much smaller gains in terms of firm creation, output, and consumption. The scarcity of deposits - the major source of funds - limits the economy's capacity to fully exploit such gains as the rising interest rate crowds out some of the new investment. Despite accelerated credit reallocation, this effect is weak as liquidation remains costly.

A more efficient restructuring process reduces banks' reliance on external deposits and mitigates the crowding-out. We consider a scenario which combines the R&D subsidy with a simultaneous improvement of the restructuring process (e.g., reform of insolvency laws). We simulate a gradual reduction of the liquidation cost c by 5.5 percent in parallel to introducing the subsidy. This intervention mitigates the crowding-out by keeping the steady-state interest rate in the low-elasticity ($\eta = 0.3$) scenario at the same level as it would be in the high-elasticity ($\eta = 1.2$) scenario, namely, at $i = 2.13\%$.[10]

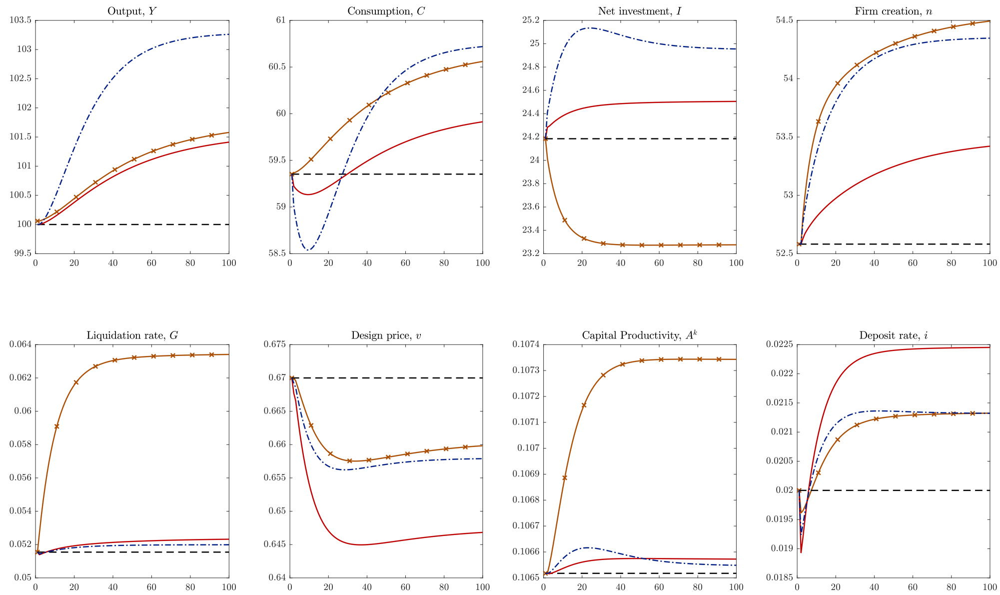

Figure 4: *Simulation results: Complementarities*

Figure 4 shows the consequences of introducing a five percent R&D subsidy if (i) $\eta = 0.3$ (red, solid line), (ii) $\eta = 1.2$ (blue, dashed line), and (ii) $\eta = 0.3$ and c is simultaneously lowered by 5.5 percent (gold, line marked by x). There are complementarities between the efficiency of entry and exit margin: Combining the R&D subsidy with improved insolvency laws raises the share of liquidated loans from 5.15 to 6.35 rather than only 5.24 percent. Increased credit reallocation and firm exit reduce banks' deposit demand and limit the pressure on the deposit rate caused by the subsidy. The weaker interest rate effect curbs the decline in producer profits, leading to a relatively higher design price v. This reinforces the stimulating effect of the R&D subsidy. The increase in firm creation more than doubles.

Despite higher entry rates, the output gains remain unchanged compared to a standalone introduction of the R&D subsidy in the low-elasticity scenario (1.7% instead of 1.6%).

[10]Unlike in Section 3.2.2, we do not completely neutralize the interest rate effect but limit its size.

Output gains are lower than in the high-elasticity scenario with a standalone R&D subsidy (3.3%) because of the liquidation effect. Unlike the R&D subsidy alone, the combined policy boosts aggregate capital productivity as increased loan liquidation accelerate the exit of unproductive ℓ-firms and reduces net capital and investment. Therefore, the consumption gains of 2.3 percent are significantly larger than a introducing a standalone subsidy under inelastic deposits (1.2%) and roughly similar to doing so under elastic deposits (2.4%). The combined policy also avoids temporary consumption losses in the beginning due to increased investment.

5.3 Discrete Effects

Banks support capital reallocation by redirecting credit from low-productivity firms with poor prospects to more productive entrants. While relaxing the economy's resource constraint, reallocation is not without frictions, which we broadly represent by imperfect information in monitoring. This section addresses two questions: How large is the discrete contribution of bank credit reallocation to aggregate outcomes despite monitoring imperfections? And what are the potential gains from eliminating imperfect information in bank monitoring? For that purpose, we compute the discrete effects by comparing the initial steady state (ISS) with two counterfactual benchmarks: (i) a stationary equilibrium with an uninformative performance signal (i.e, $\alpha_1 = \alpha_2$) such that banks, lacking any new information, refrain from restructuring non-performing loans altogether. The share of liquidated loans is zero, $G(s) = 0$, and the exit rate of ℓ-firms equals the exogenous destruction probability, $1 - \phi = 1 - q$; (ii) a stationary equilibrium in which the signal precisely reveals the destruction shock of each borrower. When restructuring loans, banks avoid any errors: They continue all q performing ℓ-loans and liquidate all $1-q$ non-performing ones, releasing $(1-c)(1-q)N_t^\ell$ of funds for new lending. Table 3 provides a comparison of steady states distinguishing between high and low interest rate elasticities of deposits.

Uninformative Monitoring: If banks do not receive new information about their borrowers' prospects (cols. 2-3), they cannot restructure loans. The survival rate of ℓ-firms rises to $\phi = q = 91\%$. Expected firm lifetime increases, the stationary mass of producers,

	ISS	Uninform. Monitoring		Perfect Monitoring	
		$\eta = 0.3$	$\eta = 1.2$	$\eta = 0.3$	$\eta = 1.2$
Output Y	100	99.7	103.89	109.28	117.76
Consumption C	59.35	57.31	59.14	77.08	81.69
Net investment I	24.19	28.71	29.94	15.8	17.03
Deposit rate i	2%	2.58%	2.32%	3.15%	2.60%
Design price v	0.67	0.61	0.64	0.67	0.72
Firm creation n	52.58	48.86	49.89	52.48	56.55
Liquidated loans $G(s)$	5.15%	0%	0%	9%	9%
Survival rate ϕ	89%	91%	91%	91%	91%
Non-performing loans NPL	3%	4.95%	4.95%	0%	0%
Share h-firms μ^h	50%	45%	45%	45%	45%
Avg. output/firm A^f	0.105	-1.45%	-1.45%	-1.45%	-1.45%
Net capital/firm κ	0.982	+1.83%	+1.83%	-1.69%	-1.69%
Aggr. capital prod. A^k	0.107	-3.23%	-3.23%	+0.24%	+0.24%

Table 4: *Discrete effects*

and aggregate output increase. Importantly, banks need to finance a larger volume of credit to an even larger extent with deposits, which raises the deposit rate by 0.3 to 0.6 percentage points. This interest rate effect that is pronounced if deposits are inelastic diminishes the design price from 0.67 to 0.64 and 0.61, respectively. Firm creation drops by 5.1 and 7.1 percent compared to in the initial steady state.

The absence of loan liquidation should increase aggregate output by avoiding the closure of performing firms due to monitoring imperfections. The negative entry effect, however, diminishes such output gains: Under elastic deposits with a weak interest rate effect, aggregate output is indeed 3.9 percent higher than in the initial steady state. If deposits are inelastic, in contrast, the decline in business creation more than offsets any such output gains. Net investment is roughly 20 percent higher as less capital is reallocated. Investment of entrants is financed predominantly out of household savings. These two forces determine the consumption pattern: If deposits are inelastic, stagnant output and rising net investment cause a consumption loss of 3.4 percent. If deposits are elastic, higher output keeps consumption roughly constant.

Reallocating credit improves portfolio quality and aggregate productivity. These effects are driven by changes in firm composition and are largely independent of the availability of deposits. If banks did not restructure any non-performing loans, the NPL ratio would rise by almost two thirds. Aggregate capital productivity would permanently fall by 3.23 percent due to a smaller share of high-productivity firms and larger net capital.

Perfect Monitoring: Whenever monitoring precisely reveals a borrower's destruction shock (cols. 4-5), the bank liquidates all loans to those $(1-q)N^{\ell}$ firms that will receive such a shock and thus default next period. Recovering the full liquidation value $1-c$ avoids the larger loss $1-z$. The remaining qN^{ℓ} loans to firms that experience no destruction shock and will survive the period with certainty are all continued. The share of liquidated loans, $G(s) = 1-q = 0.09$, and the survival rate of ℓ-firms, $\phi = q = 0.91$, are higher than in the initial steady state: Banks liquidate all rather than only $G_2(s) = 0.35$ of non-performing loans, while avoiding the erroneous closure of $G_1(s) = 0.022$ of otherwise performing ℓ-firms.

A higher survival rate prolongs the expected lifetime in the low-productivity state from 9.1 to 11.1 years. On the one hand, the present value of firm profits and the design price increase, encouraging firm creation. On the other hand, the longer lifetime raises credit demand of ℓ-firms, pushing up the equilibrium interest rate. This depresses firm profits in both states, again lowering the design price. The net effect on firm creation depends on the availability of deposits: With inelastic deposits, eliminating monitoring imperfections sharply raises the interest rate by 1.15 percentage points. As a result, both effects cancel out leaving the design price and firm creation unchanged. With more elastic deposits, the interest rate hike is only half as large, and firm creation increases by roughly 7.5 percent.

Targeted loan restructuring promises large aggregate output gains. If banks avoided erroneously liquidating productive ℓ-firms, aggregate output would rise by 9.3 percent. In the low-elasticity scenario, more firms are created, which increases the stationary mass of producers. Aggregate output gains double to 17.8 percent. Consumption is between 30 and 38 percent larger compared to the initial steady state. The consumption increase is due to higher output and declining net investment as banks release more funds for new lending.

The productivity effects are small because the firm composition changes: Better targeted loan restructuring extends the expected lifetime in the low-productivity state. The share of h-types falls by five percentage points, reducing average firm output. Aggregate capital productivity, however, rises as more reallocation lowers net capital.

6 Conclusion

We analyze how banks facilitate creative destruction. Banks restructure non-performing loans and thereby release funds for investment into new, more productive firms. Our dynamic general equilibrium framework combines a structural model of credit reallocation with endogenous firm creation and exit. The analysis yields three main results: (i) By reallocating outstanding credit, banks become less dependent on deposits, which keeps the equilibrium interest rate low particularly if deposits are inelastic. An efficient loan restructuring process not only improves aggregate productivity by accelerating the exit of unproductive firms, it also boosts firm creation at the technological frontier. (ii) We identify complementarities between firm entry and exit under inelastic deposits. Efficient credit reallocation renders policies that aim at stimulating firm creation (e.g., R&D subsidies) more effective by avoiding a crowding-out via higher borrowing costs. (iii) Credit reallocation offers sizable discrete gains in aggregate productivity and consumption especially if the economy's resource constraint is tight due to an inelastic supply of deposits. Reducing imperfections in monitoring and preventing costly errors in banks' liquidation decisions can further boost output and consumption gains.

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A Appendix

A.1 Model

Mutual Fund: The state variables N_t^h and N_t^ℓ follow the laws of motion in (1). Given π_t^e in (13), optimization must solve the Bellman problem (14). Given $\lambda_t^h \equiv dV_t/dN_{t-1}^h$ and $\lambda_t^\ell \equiv dV_t/dN_{t-1}^\ell$, first-order and envelope conditions are:

$$\begin{aligned} v_t &= \pi_t^h + \omega\lambda_{t+1}^h + (1-\omega)\,\lambda_{t+1}^\ell, \\ (1+r_{t-1})\,\lambda_t^h &= \pi_t^h + \omega\lambda_{t+1}^h + (1-\omega)\,\lambda_{t+1}^\ell, \\ (1+r_{t-1})\,\lambda_t^\ell &= \phi_{t-1}\pi_t^\ell + \phi_{t-1}\lambda_{t+1}^\ell, \end{aligned} \tag{A.1}$$

Households: Optimal consumption C_t and new deposits S_t solve:

$$V^h(A_{t-1}, D_{t-1}) = \max_{C_t, S_t} u(C_t, D_{t-1}) + \beta V^h(A_t, D_t) \quad s.t. \quad (17). \tag{A.2}$$

Marginal utilities are $u_{C,t} \equiv \partial u(C_t, D_{t-1})/\partial C_t$ and $u_{D,t} \equiv \partial u(C_t, D_{t-1})/\partial D_{t-1}$. The solution is given by the Euler equation and the tangency condition for deposits:

$$u_{C,t} = \beta(1+r_t)\,u_{C,t+1}, \quad \frac{u_{D,t+1}}{u_{C,t+1}} = r_t - i_t. \tag{A.3}$$

Walras' Law: We first eliminate S_t in (17) to get the consolidated budget constraint of households and substitute $A_t = V_{t+1}$ together with $V_{t+1} = (1+r_{t-1})\,V_t - \pi_t^e$,

$$D_t = (1+i_{t-1})\,D_{t-1} + (1+r_{t-1})\,(A_{t-1} - V_t) + \pi_t^e + \bar{\pi}_t - (1-w_t)\xi_t M - C_t. \tag{A.4}$$

Combine $\bar{\pi}_t = v_t n_t - T_t$, π_t^e in (13), and $(1-w_t)\xi_t M$ using the balanced budget $T_t = w_t\xi_t M$:

$$\begin{aligned} \pi_t^e + \bar{\pi}_t - (1-w_t)\xi_t M =& \pi_t^h(n_t + N_{t-1}^h) + \pi_t^\ell\phi_{t-1}N_{t-1}^\ell + \pi_t^b - \xi_t M \\ =& Y_t + (1-c)G(s_t)N_t^\ell + z(1-q)[1-G_2(s_{t-1})]N_{t-1}^\ell + S_t^d \\ & - n_{t+1} - i_{t-1}D_{t-1}^d - \xi_t M \\ =& Y_t - I_t - \xi_t M + D_t^d - (1+i_{t-1})D_{t-1}^d. \end{aligned} \tag{A.5}$$

The second equality substitutes (10) for bank dividends π_t^b using the definitions $L_t^h = n_{t+1} + N_t^h$ and $L_t^\ell = N_t^\ell$ and (2) for aggregate output Y_t. The third equality substitutes net investment I_t from (20) as well as $S_t^d = D_t^d - D_{t-1}^d$ from (6). By substituting this into the consolidated budget constraint (A.4), one proves Walras' Law:

$$D_t - D_t^d = (1 + i_{t-1}) \left(D_{t-1} - D_{t-1}^d\right) + (1 + r_{t-1}) \left(A_{t-1} - V_t\right) + Y_t - C_t - I_t - \xi_t M. \quad \text{(A.6)}$$

Since $D_{t-1} = D_{t-1}^d$ is identically fulfilled by last period's equilibrium, one of the conditions in (19) is redundant.

A.2 Theoretical Analysis

Bank's Problem: We detail the solution to (12). Shadow values and the Lagrange multiplier are denoted by $\lambda_t^{b,j} \equiv dV_t^b/dj_{t-1}$ and μ_t^b, respectively. With short-cut notation $G_t \equiv G(s_t)$ and $g_t \equiv g(s_t)$, the first-order conditions with respect to n_{t+1}, S_t^d, and s_t are:

$$-1 + \lambda_{t+1}^{b,h} + \mu_t^b(1-e) = 0, \quad 1 + \lambda_{t+1}^{b,d} - \mu_t^b = 0, \quad (1-c) g_t L_t^\ell + \lambda_{t+1}^{b,s} - \mu_t^b (1-e) g_t L_t^\ell = 0. \quad \text{(A.7)}$$

The four envelope conditions are:

$$\begin{aligned}
(1 + r_{t-1})\lambda_t^{b,h} =& i_{t-1}^h + \omega[\lambda_{t+1}^{b,h} + \mu_t^b(1-e)] + (1-\omega)[(1-c)G_t + \lambda_{t+1}^{b,\ell} + \mu_t^b(1-e)(1-G_t)], \\
(1 + r_{t-1})\lambda_t^{b,\ell} =& \phi_{t-1}[i_{t-1}^\ell + (1-c)G_t + \lambda_{t+1}^{b,\ell} + \mu_t^b(1-e)(1-G_t)] + (1-q)(1-G_{2,t-1})z, \\
(1 + r_{t-1})\lambda_t^{b,d} =& - i_{t-1} + \lambda_{t+1}^{b,d} - \mu_t^b, \qquad \text{(A.8)} \\
(1 + r_{t-1})\lambda_t^{b,s} =& - q g_{1,t-1} L_{t-1}^\ell [i_{t-1}^\ell + (1-c)G_t + \lambda_{t+1}^{b,\ell} + \mu_t^b(1-e)(1-G_t)] \\
& - (1-q) g_{2,t-1} z L_{t-1}^\ell.
\end{aligned}$$

Iterating (A.8.iii) forward, $(1 + r_t)\lambda_{t+1}^{b,d} = -i_t + \lambda_{t+2}^{b,d} - \mu_{t+1}^b$, and substituting $\lambda_{t+1}^{b,d} = \mu_t^b - 1$ from (A.7.ii) yields $\mu_t^b = (r_t - i_t)/(1 + r_t) > 0$. Since equity is expensive in equilibrium, the regulatory constraint binds, giving $E_t = eL_t$ and $D_t^d = (1-e)L_t$.

Liquidation: Define the following transformation of $\lambda_t^{b,\ell}$:

$$\tilde{\lambda}_t^{b,\ell} \equiv i_{t-1}^{\ell} + (1-c)G_t + \lambda_{t+1}^{b,\ell} + \mu_t^b(1-e)(1-G_t). \tag{A.9}$$

This is the shadow value of a loan to an ℓ-firm that survived the period. The latter yields an inflow of i_{t-1}^{ℓ}. At the end of t, the bank may liquidate, which generates an additional expected inflow of $(1-c)G_t$, or continue with a shadow value $\lambda_{t+1}^{b,\ell}$. If continued, the loan raises the stock of equity, which relaxes the regulatory constraint in proportion to $1-e$. We use (A.9) when iterating (A.8.iv) forward, $(1+r_t)\lambda_{t+1}^{b,s} = -[qg_{1,t}\tilde{\lambda}_{t+1}^{b,\ell} + (1-q)g_{2,t}z]L_t^{\ell}$. Substituting (A.7.iii) for $\lambda_{t+1}^{b,s}$, dividing by $g_t L_t^{\ell}$, and using $\bar{q}_t = qg_{1,t}/g_t$ yields:

$$(1+r_t)[(1-c) - \mu_t^b(1-e)] = \bar{q}_t\tilde{\lambda}_{t+1}^{b,\ell} + (1-\bar{q}_t)z. \tag{A.10}$$

Substituting $\mu_t^b = (r_t - i_t)/(1+r_t)$ gives (21).

Loan Rates and Shadow Values: Substituting for μ_t^b in (A.7.i) yields $(1+r_t)\lambda_{t+1}^{b,h} = 1+\bar{r}_t$. The shadow value of new h-loan must equal the weighted borrowing cost. This is a zero profit condition for new loans. We also iterate (A.8.i) forward and substitute for $\lambda_{t+1}^{b,h}$:

$$\begin{aligned}\bar{r}_t &= i_t^h + (1-\omega)[(1-c)G_{t+1} + \lambda_{t+2}^{b,\ell} + \mu_{t+1}^b(1-e)(1-G(s_{t+1})) - 1] \\ &= i_t^h + (1-\omega)[\tilde{\lambda}_{t+1}^{b,\ell} - (1+i_t^{\ell})].\end{aligned} \tag{A.11}$$

The second equality uses (A.9). If the bank makes a loss on h-loans because the competitive loan rate falls short of the borrowing cost, $i_t^h < \bar{r}_t$, it must earn a profit on ℓ-loans (i.e., the shadow value exceeds $1+i_t^{\ell}$). We henceforth focus on a competitive equilibrium in which banks break even separately on h- and ℓ-loans, giving $\bar{r}_t = i_t^h$ and $\tilde{\lambda}_{t+1}^{b,\ell} = 1+i_t^{\ell}$.

Next, we iterate (A.9) forward and substitute $\tilde{\lambda}_{t+1}^{b,\ell} = 1+i_t^{\ell}$:

$$\begin{aligned}1 &= (1-c)G_{t+1} + \lambda_{t+2}^{b,\ell} + \mu_{t+1}^b(1-e)(1-G_{t+1}) \\ &= (1-c)G_{t+1} + \frac{\phi_{t+1}\tilde{\lambda}_{t+2}^{b,\ell} + (1-q)(1-G_{2,t+1})z}{1+r_{t+1}} + \frac{r_{t+1}-i_{t+1}}{1+r_{t+1}}(1-e)(1-G_{t+1}).\end{aligned} \tag{A.12}$$

The second equality uses (A.8.ii). Multiplying by $1+r_{t+1}$, using the definition of $\bar{r}_t$, and substituting (21) for the expression in square brackets gives:

$$\begin{aligned}1+\bar{r}_{t+1} &= [1+\bar{r}_{t+1}-(1+r_{t+1})c]G_{t+1}+\phi_{t+1}\tilde{\lambda}^{b,\ell}_{t+2}+(1-q)(1-G_{2,t+1})z \\ &= (\bar{q}_{t+1}G_{t+1}+\phi_{t+1})\tilde{\lambda}^{b,\ell}_{t+2}+[(1-\bar{q}_{t+1})G_{t+1}+(1-q)(1-G_{2,t+1})]z.\end{aligned} \tag{A.13}$$

This equation must also hold at the end of period t when choices are made. Using $\varphi_t \equiv \bar{q}_t G_t + \phi_t$ and noting $(1-\bar{q}_t)G_t + (1-q)(1-G_{2,t}) = 1-\varphi_t$ one finally obtains (23).

Uniqueness: The left-hand side of (24) is $\bar{q}(s_t)$. Noting the monotone likelihood ratio property, it monotonically increases in s_t from 0 (since $g_1(1) = 0$ is assumed) to a value smaller or equal to one. The right-hand side crucially depends on the function $\varphi(s_t) = \phi_t + \bar{q}(s_t)G(s_t)$. The latter starts out at a strictly positive value $\varphi(1) = q > 0$, is monotonically increasing, $\varphi'(s) = \bar{q}'(s)G(s) > 0$, and approaches a value $\lim_{s_t\to\infty}\varphi(s_t) = \lim_{s_t\to\infty}\bar{q}(s_t) \leq 1$. The function $\varphi(s_t)$ is multiplied by the square bracket, which is independent of s_t and, for non-degenerate parameters, satisfies $1 > [\cdot] > 0$. Hence, the two lines intersect exactly once, and a unique interior cut-off s_t exists.

Comparative Statics: Competitive banks pass borrowing costs onto to firms. Since deposits are a bank's main funding source, loan rates predominantly depend on the deposit rate. Using (23) and noting $\varphi' = \bar{q}'G > 0$, one obtains

$$di^h = (1-e)\cdot di, \quad di^\ell = \frac{1-e}{\varphi}\cdot di - \frac{1+i^\ell}{\varphi}\bar{q}'G\cdot ds. \tag{A.14}$$

A higher deposit rate raises loan rates i^h and i^ℓ and thus reduces firm profits. By restructuring loans more aggressively, banks reduce the average risk of the remaining loans, which warrants a lower risk premium. The competitive loan rate i^ℓ declines in response to a higher liquidation cut-off s, to the benefit of the better part of low-productivity firms, which are able to roll over their loans.

The value of new firms ('design price') corresponds to the present value of expected profits in (3) and is $v = (1+r)\lambda^h$ with $\lambda^h = \frac{1}{1+r-\omega}\left[\pi^h + \frac{(1-\omega)\phi}{1+r-\phi}\pi^\ell\right]$, see (15). The relative price change is $\hat{v} = \hat{\lambda}^h$, which is $\hat{v} = \frac{1}{(1+r-\omega)\lambda^h}\cdot d\left[\pi^h + \frac{(1-\omega)\phi}{1+r-\phi}\pi^\ell\right]$. Higher loan rates squeeze firm profits by $d\pi^h = -di^h$ and $d\pi^\ell = -di^\ell$. We compute

$$\hat{v} = \frac{1}{(1+r-\omega)\,\lambda^h} \cdot \left[-di^h - \frac{(1-\omega)\,\phi}{1+r-\phi} \cdot di^\ell + (1-\omega)\,\pi^\ell \frac{(1+r)\,\phi'}{(1+r-\phi)^2} \cdot ds \right]. \qquad \text{(A.15)}$$

Substituting (A.14), collecting terms and using $d\phi = -qg_1 \cdot ds$ gives (28).

A.3 Calibration

Interest Rates: The annual deposit rate is $i = 0.02$ and the return on equity $r = 0.07$. The latter is consistent with the long-run real return reported by Jordà et al. (2019). The Euler equation $(1+r)\,\beta = 1$ fixes the discount factor β. The minimum capital requirements for banks are set according to the Basel III leverage ratio, $e = 0.03$.

Firm Turnover: In the model, the exit rate $1-\phi$ is defined relative to N^ℓ low-productivity firms, whereas empirical information refers to the exit rate relative to all $n + N^h + N^\ell$ firms. The two are related by $(1-\phi)N^\ell/(n + N^h + N^\ell) = [1/(1-\omega) + 1/(1-\phi)]^{-1}$. We set ω and ϕ to match an exit rate of 5.5% assuming that firms typically spend half of their lifetime in either state. In this case, transition and exit rates are the same (i.e., $\omega = \phi$). Given the annual exit rate of 5.5%, a share $1-\phi = 0.11$ of ℓ-firms exits each period, giving a survival rate of $\phi = 0.89$. Similarly, the transition rate to the low-productivity state is $1-\omega = 0.11$.

Loan Restructuring: The performance signal $s' \in [1, \infty)$ is drawn from a Pareto distribution $G_i(s') = 1 - (s')^{-\alpha_i}$. The posterior, the survival rate and the share of liquidated loans equal:

$$\bar{q}(s') = \frac{q\alpha_1(s')^{-\alpha_1}}{q\alpha_1(s')^{-\alpha_1} + (1-q)\alpha_2(s')^{-\alpha_2}}, \quad \phi = qs^{\alpha_1}, \quad G(s) = 1 - qs^{\alpha_1} - (1-q)s^{\alpha_2}. \quad \text{(A.16)}$$

We target the survival rate of $\phi = qs^{-\alpha_1} = 0.89$. For $q = 0.91$ and $\alpha_1 = 1.25$, the above condition requires $s = (q/\phi)^{1/\alpha_1} \approx 1.018$.

We calibrate α_2 to support a NPL ratio of 3%. In the model, non-performing loans correspond to ℓ-loans which are not liquidated despite a destruction shock, see (25). The steady-state NPL ratio equals:

$$NPL = \frac{(1-q)[1-G_2(s)]N^\ell}{L} = \frac{(1-q)(1-G_2(s))}{1+q(1-G_1(s))+(1-q)(1-G_2(s))}. \tag{A.17}$$

The second equality uses $\omega = \phi$ in the initial steady state. To match $NPL = 0.03$, banks must liquidate a fraction $G_2(s) = 0.351$ of loans to firms hit by a destruction shock. The parameter $\alpha_2 = -\log(1-G_2(s))/\log(s) \approx 24.58$ supports this target. With s, α_1, and α_2 known, the total share of liquidated loans is $G(s) = 0.052$, and the cut-off is $\bar{q}(s) = 0.44$. The bank terminates a loan above a default probability of 56%.

Eventually, we calibrate the liquidation cost c to ensure that the liquidation cut-off $s = 1.018$ is indeed optimal for these parameter values. By (24), we solve for $c = (1-z+\bar{r})/(1+r)(1-\bar{q}/\varphi)$ and find $c = 0.301$. With φ known and $z = 0.4$, we find $c = (1-z+\bar{r})/(1+r)(1-\bar{q}/\varphi) = 0.301$. We also solve for the loan rate $i^\ell = (1+\bar{r})/\varphi - z(1-\varphi)/\varphi - 1 = 0.081$.

Production: We calibrate output (TFP) y^h and y^ℓ to match the firm-level productivity dispersion and leverage in the firm sector. In line with empirical evidence (Syverson, 2004a,b; Bartelsman and Wolf, 2018), the output of of h-firms is 45% higher compared to ℓ-firms, $y^h = 1.45 \cdot y^\ell$. Given this output ratio, we calibrate the output level y^ℓ. Recall that each firm uses one unit of capital financed with bank credit and one product design acquired with equity at price v. In line with French data (BACH, 2012-18), we target an equity ratio in the firm sector of $v/(1+v) = 0.4$, which requires $v = 2/3$. We calculate the level y^ℓ to support this price for given interest rates.[11]

Turning to aggregate values, we normalize output to $Y = 100$. By (1), the steady-state distribution of production firms is $n + N^h = n/(1-\omega)$ and $N^\ell = n/(1-\phi)$. Using this in (2), we calculate a constant inflow $n = Y/\left(y^h/(1-\omega) + y^\ell/(1-\phi)\right) \approx 52.58$.

R&D: Start-ups are riskier than production firms, which succeed each period with probabilities 1 and $\phi = 0.89$. We thus set their success probability to $p = 0.75$. We assume that

[11]Note v in (15) and substitute profits $\pi^h = y^h - i^h = 1.45 \cdot y^\ell - i^h$ and $\pi^h = y^\ell - i^\ell$ to get:

$$y^\ell = \frac{1+r-\phi}{1.45(1+r-\phi)+(1-\omega)\phi}\left[\frac{(1+r-\omega)v}{1+r} + i^h\right] + \frac{(1-\omega)\phi i^\ell}{1.45(1+r-\phi)+(1-\omega)\phi}.$$

10% of household members are start-up entrepreneurs each period, $M = 0.1$. The mass of new designs $R = 701.09$ supports firm creation, $n = pRM$.

The R&D cost function is parametrized by:

$$\xi(R_t) = \frac{\bar{\xi}^{-1/\mu}}{1 + 1/\mu} R_t^{1+1/\mu}. \tag{A.18}$$

With $w = 0$, the first-order condition (5) implies $R = \bar{\xi}[pv/(1+r)]^{\mu}$. The coefficient $\bar{\xi} = [(1+r)/pv]^{\mu}$ supports this condition for $R = 709.09$. Following Akcigit and Kerr (2018), we assume a quadratic cost function, $\mu = 1$. This ensures an elasticity of patents to R&D expenditures of $\mu/(\mu+1) = 0.5$, which is consistent with common estimates.

Preferences: With separable preferences (16), the supply of deposit is purely determined by the interest rate spread and equals:

$$D = \frac{\psi}{(r-i)^{\eta}}, \quad \eta = -\frac{\partial D}{\partial (r-i)} \frac{r-i}{D}. \tag{A.19}$$

η is the elasticity of the deposit supply defined with respect to the interest rate spread $r - i$. We explore two scenarios with values $\eta = \{0.3, 1.2\}$ from the lower and upper end of empirical estimates. Accordingly, we calibrate the parameter ψ to match the supply and demand of deposits for each elasticity. This ensures the initial steady state is the same in both scenarios.