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Risk shifting and the allocation of capital: A Rationale for macroprudential regulation

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ABSTRACT

This paper reconsiders the risk-shifting problem of banks and presents a novel rationale for macroprudential regulation. The interplay between this agency problem and equilibrium investment creates a welfare-reducing pecuniary externality that causes capital misallocation and excessive bank risk taking. Therefore, the banking sector tends to be too large, under-capitalized, and inefficiently risky. This distortion is independent of typical frictions like government guarantees or default costs. Macroprudential regulation with capital requirements or deposit rate ceilings corrects misallocation thereby magnifying rent opportunities for banks to reduce risk shifting. Regulation is, however, no Pareto improvement and causes redistribution from households to bank owners.

1. Introduction

Since the global financial crisis, important regulatory reforms have been implemented to enhance the stability of the banking sector. Consistent with the macroprudential approach to bank regulation, many of the new regulatory instruments (e.g., countercyclical capital buffer, leverage ratio) address risks that emerge from the interplay between the banking system and the macroeconomy, for instance, in the form of credit cycles or excessive leverage. A related phenomenon that recently drew attention especially in the Eurozone periphery is whether the financial sector itself contributes to capital misallocation between firms and industries. Policymakers also consider the recent reforms (e.g., Basel III, Banking Union) as measures to address this problem and to strengthen bank's role in allocating capital more efficiently.[1]

The present paper analyzes how informational frictions in banking cause capital misallocation in the economy at large and how macroprudential regulation can alleviate this distortion. It addresses this question in three steps: First, we suggest a new micro-foundation of capital misallocation in the form of overinvestment of small, bank-dependent firms and underinvestment of large firms relying on market finance. Specifically, the interplay between frictions in bank risk taking and equilibrium investment create a welfare-reducing pecuniary externality. Second, the paper shows which regulatory instruments can internalize this externality and how they should be adjusted to changes in the economic environment. Third, we highlight the distributional consequences of macroprudential regulation to evaluate whether it is a Pareto improvement.

This paper sets out a static general equilibrium model of an economy with (i) a banking sector where firms borrow from banks that exhibit an agency problem and (ii) a frictionless sector where firms directly borrow from households via the bond market. The main friction is asymmetric information in bank risk taking. It creates moral hazard such that banks with large debt or high borrowing costs take more risks by investing in an under-diversified loan portfolio (risk shifting). The degree of diversification determines the endogenous risk of bank failure. Unlike in partial equilibrium models with an elastic deposit supply (e.g., Repullo, 2013), deposits are scarce because households can alternatively buy corporate bonds. Sectoral investment therefore influences risk-taking incentives of banks in equilibrium via their capital structure of banks and the deposit rate. Comparing the competitive equilibrium to the preferred allocation of a planner subject to the same informational constraints as agents identifies distortions that motivate macroprudential regulation. A comparative statics analysis even-

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[1] See, for example, Speech by Mario Draghi at the presentation ceremony of the Schumpeter award, Vienna, March 2014.

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tually shows how regulators should respond to economic shocks, specifically, to changes in aggregate bank equity and productivity.

Our analysis yields three main results: First, it identifies a novel pecuniary externality as the source of capital misallocation in the economy at large and excessive bank risk taking. Intuitively, competitive banks ignore that attracting deposits affects aggregate investment thereby increasing the marginal return in the frictionless sector. The corporate bond return thus rises, and households demand a higher deposit interest rate. This equilibrium effect tightens incentive and participation constraints and ultimately exacerbates risk shifting of all banks. Hence, the banking sector is too large, overly indebted, and risky in market equilibrium. We show that this pecuniary externality rests on the combination of risk shifting, inelastically supplied deposits, and scarce bank equity.

Second, the pecuniary externality motivates macroprudential regulation. Importantly, this externality still exists and suggests a role for such regulations in the absence of typical frictions and institutional problems in banking like mis-priced deposit insurance, implicit guarantees or default costs. Specifically, we show that capital requirements or deposit rate ceilings can internalize this externality and correct misallocation and excessive risk taking. Such regulations should be adjusted to macroeconomic shocks in a nuanced fashion. For example, regulators should tighten capital requirements if a downturn is driven by a productivity decline but relax them if it is characterized by especially scarce equity ('capital crunch').

Third, macroprudential regulation is no Pareto improvement. To discourage risk shifting, the borrowing costs of banks must be kept artificially low compared to the market outcome. Bank owners benefit from larger profits, while households who provide deposits and purchase bonds earn lower asset returns. Equilibrium effects also affect labor income as bank-dependent firms attract less capital and pay lower wages, while the reverse is true for market-financed firms.

Our work connects to the literature on (i) bank risk taking, (ii) capital misallocation, and (iii) macroprudential regulation. First, the theoretical literature usually models risk taking as the portfolio choice of banks and highlights informational frictions that cause risk shifting. Indebted banks have strong incentives to take excessive risks by investing in high-risk, high-return assets or underdiversified portfolios. In general, equity increases the 'skin in the game' of bank owners and thus alleviates risk shifting. The bank's charter value (i.e., the present value of future profits) has a comparable disciplining effect.

Since capital structure and charter values are endogenous, the literature emphasizes several more fundamental determinants of risk taking, most notably, capital regulation and bank competition. Minimum capital requirements typically alleviate risk shifting because they put equity at risk and thereby reduce the value of exploiting limited liability (e.g., Rochet, 1992; Hellmann et al., 2000; Repullo, 2004).[2] Competition, in turn, influences risk taking mainly via profits and rents. Intense competition in deposit markets increases borrowing costs and erodes bank profits. This creates an incentive for excessive risk taking, see, for example, Keeley (1990), Allen and Gale (2000, 2004), and Repullo (2004). Competition in loan markets may, in contrast, reduce risk shifting of bank borrowers by lowering loan rates as demonstrated by Boyd and De Nicoló (2005). Recent theoretical research therefore draws more ambiguous conclusions about the competition-stability nexus (e.g., Hakenes and Schnabel, 2011; Martinez-Miera and Repullo, 2010).

The present paper follows Hakenes and Schnabel (2011) in modeling risk taking as portfolio diversification. One key mechanism, namely, attracting deposits exacerbates risk shifting by raising the deposit rate, is similar to models of deposit market competition. The main difference is the general equilibrium perspective: Instead of the common reduced-form deposit supply and loan demand, we explicitly model households' and firms' choices. This relates risk shifting of banks to misallocation, which is new in this literature. We also abstract from imperfect competition in banking markets to focus on general equilibrium effects that emerge because bank- and market-based sectors 'compete' for scarce capital. Our results suggest that competition beyond traditional loan and deposit markets is important for the competition-stability nexus.

Although the evidence on bank competition and stability is mixed, there is empirical support for the underlying mechanism that rising borrowing costs increase bank risk. Research in the tradition of the charter value hypothesis shows that banks' rents measured by Tobin's Q tend to lower risk (e.g., Demsetz et al., 1996; Keeley, 1990; Salas and Saurina, 2003). Some estimates specifically suggest that loan portfolio concentration and loan losses, which measure risk taking more directly, decrease in the charter value. Moreover, this mechanism is consistent with empirical evidence that negatively relates market power or bank concentration to bank failure and asset risk (e.g., Beck et al., 2006, 2013; Jiménez et al., 2013). One estimate of Beck et al., 2013 specifically suggests that smaller marginal costs of banks (e.g., lower borrowing costs) reduce bank risk.

Second, this paper highlights how frictions in bank risk taking contribute to capital misallocation in the economy at large. Misallocation between firms (e.g., Gopinath et al., 2017; Hsieh and Klenow, 2009) and, to a lesser extent, between sectors (e.g., Reis, 2013) is quantitatively important and explains part of the large productivity differences across countries. While financial intermediaries usually help improve allocative efficiency (Wurgler, 2000), they can become a source of misallocation. An economy is considered 'overbanked' whenever banks provide inefficiently large amounts of credit. Such overinvestment may result from deposit insurance or government bailouts as emphasized by Gersbach et al., 2015 and Britz et al. (2017).

Our analysis suggests a novel, bank-specific explanation for capital misallocation, namely, a pecuniary externality that causes overinvestment of banks and bank-dependent firms and underinvestment of market-financed firms. This distortion emerges irrespective of bailouts and guarantees emphasized in previous research (e.g., Britz et al., 2017) but rests on informational frictions in bank risk taking combined with inelastic deposits.

Third, this paper contributes to the literature on macroprudential regulation and pecuniary externalities. The latter may emerge if atomistic agents ignore price reactions and are the source of second-best inefficiencies if information is imperfect and markets are incomplete (Greenwald and Stiglitz, 1986). A common mechanism in finance are amplification effects due to collateral or borrowing constraints (e.g., Davila and Korinek, 2018; Lorenzoni, 2008; Suarez and Sussman, 1997). Several papers analyze how macroprudential regulation can address this phenomenon: Gersbach and Rochet (2012, 2017) highlight that banks neglect asset price reactions and thereby contribute to excessive fluctuations or misallocation between good and bad states of the economy. Related papers with pecuniary externalities are Tressel and Verdier (2014), who study collusion between bankers and borrowers, and Malherbe (2015), who points to general equilibrium effects associated with the loan rate and default costs.

The present paper is the first in this literature to introduce risk shifting as the central friction that creates a pecuniary externality rather than financial constraints or default costs. This is the main conceptual difference to Gersbach and Rochet (2017) who apply a comparable sectoral structure. Their main friction is, however, a borrowing constraint of banks (due to non-pledgeability), and they identify a pecuniary externality associated with asset prices

[2] Nevertheless, counteracting effects may exist due to the high private costs of equity as pointed out by Hellmann et al. (2000) or Hakenes and Schnabel (2011).

instead of deposit rates. Not only is our approach consistent with the importance of bank risk taking, it also allows for several new results: Since we endogenize bank failure risk, we can show that the pecuniary externality undermines financial stability in addition to creating misallocation. Furthermore, this externality is an equilibrium and not a cyclical phenomenon and permanently distorts capital allocation.

The remainder of this paper is organized as follows: Section 2 sets out the model. Subsequently, Section 3 provides a first-best benchmark, introduces moral hazard, and analyzes both the market equilibrium and the preferred allocation of a planner given asymmetric information. Section 4 discusses how macroprudential tools can implement the constrained social optimum, provides comparative statics, and sheds light on the distributional consequences. Eventually, Section 5 concludes.

2. The model

Consider an economy consisting of a banking and a frictionless sector financed via the capital market. Both sectors use capital and labor, which are complements, to produce a homogeneous good with distinct technologies:

Assumption 1. The banking technology is risky. Capital L and labor N_E yield $R(L, N_E)$ with probability p and 0 with the complementary probability $1-p$. The technology exhibits constant returns to scale. The marginal products satisfy $R_L(L, N_E) > 0 > R_{LL}(L, N_E)$ and $R_N(L, N_E) > 0 > R_{NN}(L, N_E)$ as well as $\lim_{L\to 0} R_L(L, N_E) = \infty$.

Assumption 2. The frictionless technology is risk-free. Capital X and labor N_C yield $F(X, N_C)$. The technology exhibits constant returns to scale. The marginal products satisfy $F_X(X, N_C) > 0 > F_{XX}(X, N_C)$ and $F_N(X, N_C) > 0 > F_{NN}(X, N_C)$ as well as $\lim_{X\to 0} F_X(X, N_C) = \infty$.

One can think of two sectors of the economy or of two stylized types of firms that employ different technologies and differ in the access to finance (e.g., large market-financed corporations and risky, bank-dependent SME). A similar setup is applied in prior work on macroprudential regulation (e.g., Lorenzoni, 2008; Gersbach and Rochet, 2012; 2017).

There is a continuum of measure one of identical *bankers* who own and operate banks. Each of them receives endowment $K_B > 0$ and sets up a bank that provides credit L to firms that invest in the banking technology. Loan risks are positively but imperfectly correlated, depending on the banker's endogenous diversification effort (risk taking). The bank raises equity $K \le K_B$ from its owner, who is protected by limited liability, and deposits D from households. Moreover, competitive firms in the two sectors differ in technology and access to finance: *Corporate firms* issue bonds and operate the frictionless technology. They produce with capital X and labor N_C. *Entrepreneurial firms* borrow from banks and operate the banking technology. They invest L and hire labor N_E to produce output. Eventually, a continuum of *households* receive endowment $V > 0$. They can invest in bank deposits and corporate bonds. Each household inelastically supplies one unit of labor. Labor is specialized: A fraction N $(1-N)$ of households can only work in the banking (frictionless) sector. Aggregate wealth is normalized to one, $K_B + V = 1$. All agents are risk-neutral and consume at the end of the period.

The timing is as follows: (i) Each banker opens a bank that raises deposits and equity, households allocate savings to deposits and corporate bonds, and corporate firms issue bonds and invest in the frictionless technology; (ii) banks lend to entrepreneurial firms, which invest in the banking technology, and thereby determine the correlation of loan risks (risk taking); and (iii) output is produced and successful firms repay loans and bonds and pay wages, bankers appropriate profit income, households receive capital and labor income, all agents consume. The sequential structure of the banker's choices creates moral hazard if risk taking is unobservable.

2.1. Bankers

Each banker owns and operates one bank that intermediates funds from investors to entrepreneurial firms. The bank attracts uninsured deposits D from investors, who require an expected gross return r_D, and equity K from the banker (its owner), who invests the remainder of her wealth $K_B - K$ in corporate bonds with a risk-free gross return r_B. The bank grants total loans $L = D + K$ with a gross loan rate r_L. Loans are risky, and each borrower only repays the loan with probability p.

Risk taking: Bankers choose the risk profile of their loan portfolios after they raise deposits and equity. Since banks finance many risky borrowers, the correlation of loan default risks is especially important and therefore considered endogenous. After all, banks can diversify idiosyncratic risks but may fail after correlated defaults. Adopting a stylized approach suggested by Hakenes and Schnabel (2011), we model risk taking as the banker's choice of portfolio diversification z:

Assumption 3. With probability z, loan risks turn out to be independent, and the bank receives a deterministic loan repayment from a fraction p of firms. With the complementary probability $1-z$, loan risks turn out to be perfectly correlated, and the bank is either repaid by all firms (prob. p) or by none (prob. $1-p$).

z is the endogenous probability of a perfectly diversified loan portfolio. A bank is insolvent whenever the portfolio is perfectly correlated and all borrowers simultaneously default. The probability of bank failure is $(1-z)(1-p)$. With probability $z + (1-z)p$, it remains solvent as either all or a sufficient fraction of loans are repaid.[3]

In reality, the degree of portfolio diversification relates to a bank's business model: Regional or mortgage banks, for example, are rather specialized lenders that finance borrowers more exposed to common shocks (e.g., shocks to the regional economy), while universal or international banks usually have more diversified portfolios.

Like in Hakenes and Schnabel (2011), the banker incurs an effort cost (management cost) $C(z)L$ when extending credit. It depends on portfolio diversification and is proportional to total loans:

Assumption 4. The cost function $C(z)$ is u-shaped with a minimum at $z_0 \in (0, 1)$, $C'(z_0) = 0$. It satisfies $C'(z) < 0$ for $z < z_0$ and $C'(z) > 0$ for $z > z_0$, and $C''(z) > 0$.

One may interpret z_0 as the 'natural correlation' of risks among entrepreneurial firms. Any deviation from this level is costly, and $C(z)$ is a diversification cost for $z > z_0$ and a specialization cost for $z < z_0$, respectively. Alternatively, it may represent a combination of private bankruptcy costs and the effort cost of diversifying loan risks.[4] For $z > z_0$, the banker faces the classical trade-off between risk and return because a more diversified portfolio is safer but

[3] We conjecture that the bank's equilibrium interest earnings, r_L or pr_L, will cover liabilities in these two cases. We later verify that the loan rate is always larger than the contractual deposit rate, $r_L \ge b$. Together with $L \ge D$, this ensures solvency if the portfolio turns out to be correlated and successful such that all loans are repaid. Solvency in case the portfolio is perfectly diversified and a fraction p of loans are repaid, $pr_L L \ge bD$, requires an implicit assumption about the success probability p or equilibrium bank equity $K = L - D$.

[4] Specifically, there are a private bankruptcy cost ψ, which materialize in case of failure (e.g., reputation loss), and a convex and increasing diversification cost $c(z)$ (e.g., for monitoring and screening). The total cost is $C(z) = (1-p)(1-z)\psi + c(z)$ with a minimum at z_0, $C'(z_0) = -(1-p)\psi + c'(z_0) = 0$.

entails higher costs. For $z < z_0$, in contrast, more diversification lowers risk and costs alike.

Deposits: Risk-neutral households require an expected gross return on uninsured deposits r_D that competitive banks take as given. Precisely, banks compete in deposit (debt) contracts because they may fail depending on how diversified their portfolios are. Such a contract specifies the repayment equal to the risk-adjusted rate b in case of success and zero else. Noting the failure probability $(1-z)(1-p)$, the deposit contract must satisfy the participation constraint:

$$[z + (1-z)p]b = r_D. \tag{1}$$

Profit: Bank profit is (i) deterministic and equal to $pr_L L - bD$ if the loan portfolio is perfectly diversified (prob. z) or (ii) stochastic and either equal to $r_L L - bD$ with probability p and zero with probability $1-p$ in case it is perfectly correlated (prob. $1-z$). Ex ante, banks expect a profit of

$$\pi^B \equiv [pr_L - (z + (1-z)p)b(1-\kappa)]L, \quad \kappa \equiv \frac{K}{L} \tag{2}$$

The capital ratio κ is endogenous, depending on equity and loans. The expected utility of a banker who invests $K \le K_B$ as bank equity and uses the remainder $K_B - K$ to buy corporate bonds with safe return r_B is $\upsilon^B \equiv \pi^B + r_B(K_B - K) - C(z)L$.

Portfolio diversification does not affect expected interest earnings, which are equal to pr_L irrespective of whether loan defaults turn out to be correlated or diversified. However, it does affect the expected repayment of deposits $(z + (1-z)p)bD$. The latter rises with z, an well diversified banks are more likely to repay deposits.

2.2. Firms

Entrepreneurial firms in the banking sector are financed by credit, while corporate firms in the frictionless sector directly borrow from households and bankers. Firms are competitive, and there exists a large pool of potential entrants to either sector (free entry).

Entrepreneurial firms: They produce output $R(L, N_E)$ with probability p using capital L and labor N_E. Entrepreneurial firms borrow from banks. They pay a gross interest rate r_L and a wage w_E if successful and maximize expected profit:

$$\pi^E = \max_{L,N_E} p[R(L, N_E) - r_L L - w_E N_E]. \tag{3}$$

Optimal investment and labor are characterized by the first-order conditions $R_L(L, N_E) = r_L$ and $R_N(L, N_E) = w_E$. Expected firm profits are zero, $\pi^E = 0$, because the technology exhibits constant returns to scale (Assumption 1) and capital and labor are paid according to the marginal products.

Corporate firms: They invest X and hire labor N_C to produce output $F(X, N_C)$. Corporate firms issue riskless bonds with a gross return r_B and offer a wage w_C. Investment and labor maximize profits

$$\pi^C = \max_{X,N_C} F(X, N_C) - r_B X - w_C N_C \tag{4}$$

whenever the first-order conditions hold, $F_X(X, N_C) = r_B$ and $F_N(X, N_C) = w_C$. Again, firm profits are zero, $\pi^C = 0$, on account of constant returns to scale.

2.3. Households

A mass one of households save V for end of period consumption and can invest in bank deposits and corporate bonds. Deposits D promise an expected interest rate r_D; bonds $V - D$ yield a safe return r_B. Risk-neutral households only purchase the asset with a higher expected return. Banks and corporate firms can thus only attract funds in equilibrium if expected returns on deposits and bonds are equalized, giving the no-arbitrage condition:

$$r_D = r_B. \tag{5}$$

In addition, each household inelastically supplies one unit of labor. Disutility of labor is normalized to zero, such that welfare equals income (consumption). We assume that labor is specialized and can exclusively be used in one sector, for example, because of specific skills like entrepreneurial ability. A fixed share $N \in (0, 1)$ of households can work in the banking sector. They earn an expected wage pw_E at the end of the period, which adds to capital income. The remainder $1 - N$ can work in the frictionless sector and earns a wage w_C. Noting that asset portfolios are independent of wages, individual income equals $\pi_E^H = r_D D + r_B(V - D) + pw_E$ and $\pi_C^H = r_D D + r_B(V - D) + w_C$ respectively, giving aggregate household income:

$$\pi^H \equiv \pi_E^H \cdot N + \pi_C^H \cdot (1-N) = r_D D + r_B(V - D) + pw_E N + w_C(1-N). \tag{6}$$

2.4. Markets

In this economy, three capital markets exist: a loan market where entrepreneurial firms borrow from banks, a deposit market where banks raise deposits from households, and a bond market where households and bankers purchase bonds issued by corporate firms. Furthermore, there are two separate labor markets where entrepreneurial and corporate firms hire specialized labor supplied by households. The market clearing conditions for deposit, bond, and labor markets are:

$$D = L - K, \quad X = V - D + K_B - K, \quad N_E = N, \quad N_C = 1 - N. \tag{7}$$

3. Analysis

This section first establishes a full-information benchmark (first best). After introducing moral hazard, it characterizes (i) the allocation chosen by a regulator or planner who maximizes social welfare and faces the same informational constraints as the agents (constrained social optimum) and (ii) the competitive market equilibrium under asymmetric information. Social welfare is utilitarian and equals aggregate income of bankers and households net of effort costs, $W \equiv \upsilon^B + \pi^H = F(X, N_C) + pR(L, N_E) - C(z)L$. A comparison of market equilibrium and constrained social optimum eventually identifies the main distortions.

3.1. First best

With full information, the first best follows from welfare maximization subject to resource constraints:

Program 1. The planner maximizes social welfare by choosing sectoral investment and labor, L and X as well as N_E and N_C, and portfolio diversification z

$$W = \max_{L,X,z,N_E,N_C} F(X, N_C) + pR(L, N_E) - C(z)L \tag{8}$$

subject to the resource constraints

$$L + X = 1, \quad N_E \le N, \quad N_C \le 1 - N. \tag{9}$$

The first-order conditions characterize the efficient allocation:

$$\begin{aligned} &F_X(X, N_C) = pR_L(L, N_E) - C(z), \quad -C'(z) = 0, \\ &L + X = 1, \quad N_E = N, \quad N_C = 1 - N. \end{aligned} \tag{10}$$

The following proposition summarizes the first best:

Proposition 1. *The first-best allocation $\{\widetilde{L}, \widetilde{X}, \widetilde{z}, \widetilde{N}_E, \widetilde{N}_C\}$ satisfies (10). Marginal returns to capital are equalized across sectors, and portfolio* *diversification minimizes costs, $z = z_0$. Banks' profit margin $pr_L - r_D$ covers management costs $C(z)$. The wealth distribution does not affect welfare, and the capital structure of banks is not unique.*

Proof. Resource constraints for labor bind due to $F_N(X, N_C) > 0$ and $pR_N(L, N_E) > 0$. Efficient risk taking $z = z_0$ follows from $C'(z) = 0$, see Assumption 4. The result on the profit margin is implied by the second equation: With optimal choices, $R'(L) = r_L$, $F_X(X, N_C) = r_B$, and $r_B = r_D$, the profit margin becomes $pr_L - r_D = C(z)$. The irrelevance of the wealth distribution follows from $\partial W/\partial K_B = 0$. The capital ratio of banks is not unique as (10) only pins down sectoral investment L and X. □

This allocation can be decentralized as a competitive market equilibrium in a frictionless economy. The irrelevance of the wealth distribution and the indeterminacy of the capital structure are typical Modigliani-Miller results. In principle, many capital ratios $\kappa \leq K_B/\widetilde{L}$ are compatible with equilibrium as equity has no advantage over debt.[5]

3.2. Moral hazard and risk shifting

Risk taking is characterized by informational frictions that give rise to moral hazard. After all, outsiders can often not precisely assess the risk profile of a bank's large, opaque loan portfolio. We thus assume that bank risk taking is not observable:

Assumption 5. The degree of portfolio diversification z and the management cost $C(z)$ are private information of the banker.

Depositors do observe the capital ratio and the bank's earnings, which are either r_L, pr_L or 0. They know whether the portfolio turned out to be diversified or correlated but they can neither observe nor infer the underlying probability of a perfectly diversified portfolio z. Since risk taking is not contractible, the contract space is the risk-adjusted interest rate b, capital ratio κ, and realized earnings. The banker offers a debt contract that promises b per unit conditional on positive interest earnings and 0 else. Depositors observe the earnings and demand full repayment whenever those earnings are sufficient. This rules out that the banker understates the true earnings to reduce the repayment.

The debt contract must therefore satisfy both the participation constraint of households (1) and the incentive compatibility constraint of the banker. The latter requires that portfolio diversification is privately optimal ex post and maximizes the banker's expected utility $v^B = \pi^B + r_B(K_B - K) - C(z)L$ conditional on the deposit rate b and capital ratio κ set at an earlier stage:

$$z = \arg\max_z [pr_L - (z + (1-z)p)b(1-\kappa) - C(z)]L + r_B(K_B - K). \quad (11)$$

Risk taking is characterized by the first-order condition:

$$-(1-p)b(1-\kappa) - C'(z) = 0. \quad (12)$$

The banker trades off the gains from exploiting limited liability and the marginal management costs. A more diversified portfolio reduces bank failure risk in proportion to $1 - p$ and thus diminishes any gains from defaulting on deposits $b(1 - \kappa)$. Eq. (12) implies that the marginal cost, $C'(z) = -(1-p)b(1-\kappa) < 0$, is negative provided that the bank is indebted ($\kappa < 1$). Under moral hazard, the bank overspecializes with a portfolio that is more correlated relative to the cost-efficient level, $z < z_0$, despite a strictly positive specialization cost. This is a standard risk-shifting result: Since only solvent banks have to repay debt, a more correlated portfolio diminishes the expected cost of debt thereby increasing expected bank profit. Importantly, risk shifting occurs even though deposits are correctly priced in equilibrium.

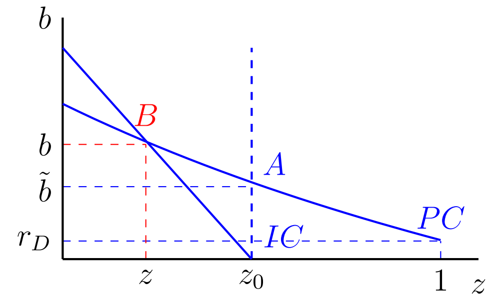

Fig. 1. Risk Shifting and Feasible Contract This figure illustrates PC and IC, (1) and (12). In the first best, the IC is eliminated, giving point A. With moral hazard, the financing contract is point B.

Fig. 1 illustrates. The IC-curve includes all combinations of deposit rate b and risk taking z that are incentive-compatible and consistent with (12), the PC-curve all combinations that satisfy the participation constraint (1). Both are downward-sloping: The former because a lower deposit rate alleviates risk shifting leading to a more diversified portfolio, the latter since investors require a lower interest rate if portfolios are better diversified and banks are safer. The set of feasible contracts is given by the segment of the IC-curve above the intersection of IC and PC as well as by the intersection point. Moving rightwards raises bankers' expected utility such that point B defines the financing contract under asymmetric information. The dashed, vertical line represents the first best with point A denoting the efficient contract.

Both constraints are endogenous: A higher capital ratio κ diminishes any gains from exploiting limited liability. The IC-curve becomes steeper; for $\kappa = 1$, it is vertical leading to the first best (point A). A higher required return on deposits r_D, in turn, shifts up the PC-curve. If the two curves did not intersect, no feasible debt contract would exist, and banks could not attract deposits in the first place. Such a case might happen if banks were poorly capitalized, $\kappa < \kappa_0$, where $\kappa_0 \geq 0$ is the capital ratio for which IC and PC just intersect or are tangent. This case can be ruled out because κ is endogenous, and bank stabilize the capital ratio whenever the latter approaches its lower bound, $\kappa \to \kappa_0$.

Risk taking and deposit rate are implicitly determined by (1) and (12):

Lemma 1. *Under moral hazard, portfolio diversification and the risk-adjusted deposit rate depend on the capital ratio and the required return on deposits:*

$$z = z(\kappa, r_D), \quad b = b(\kappa, r_D). \quad (13)$$

A higher capital ratio and a lower required return on deposits increase the degree of portfolio diversification and lower the deposit rate.

Proof. Appendix A.1 derives $\frac{\partial z}{\partial \kappa} > 0 \geq \frac{\partial z}{\partial r_D}$ and $\frac{\partial b}{\partial \kappa} < 0 < \frac{\partial b}{\partial r_D}$.

3.3. Constrained social optimum

The preferred allocation of a welfare-maximizing planner or regulator whose choices are subject to the very same informational constraint as the agents establishes the benchmark under asymmetric information.

3.3.1. The Regulator's problem

The regulator does not control risk taking but instead needs to anticipate the incentives of the banker who maximizes her own expected welfare, see (11) - (12). Portfolio diversification thus depends on the capital ratio κ and the deposit rate b, unlike in

[5] There is one restriction: Noting $r_L = R_L(L, N_E)$ and $r_D = [z + (1-z)p]b$, the first condition of (10) becomes $pr_L = [z + (1-z)p]b + C(z)$ in market equilibrium and implies $r_L > b$. A bank is thus solvent if all loans are repaid. However, solvency if only a share p of loans is repaid (diversified portfolio), $pr_L \geq b(1-\kappa)$, might require $\kappa > 0$.

the first best. The latter cannot be freely chosen because it needs to ensure participation of investors, see (1). This rules out $b = 0$, which would eliminate risk shifting altogether.

Hence, the planner decides about sectoral investment and bank capital structure anticipating the subsequent risk-taking choice of bankers, $z = z(\kappa, r_D)$, implied by incentive compatibility and participation constraints (Lemma 1). Most importantly, the planner considers prices endogenous: The expected return on deposits r_D must match the marginal return of the alternative investment opportunity, namely, the frictionless technology, $r_B = F_X(X, N_C)$ (no-arbitrage). Investors would otherwise either purchase only bonds or deposit their entire savings with banks. In equilibrium, risk taking thus depends on the capital ratio and, via borrowing costs, on sectoral investment, $z = z[\kappa, F_X(X, N_C)]$.

Program 2. The regulator maximizes social welfare by choosing sectoral investment and labor, L and X as well as N_E and N_C, and bank equity K

$$W = \max_{L,X,K,N_E,N_C} F(X, N_C) + pR(L, N_E) - C[z(\kappa, F_X(X, N_C))]L \tag{14}$$

subject to the resource constraints $L + X = 1$, $N_E \leq N$, and $N_C \leq 1 - N$ and the capital availability constraint $K \leq K_B$. The regulator thereby anticipates bank risk taking $z = z(\kappa, r_D)$ (Lemma 1) and no-arbitrage in equilibrium, $r_D = F_X(X, N_C)$.

3.3.2. Preferred allocation under asymmetric information

The constrained social optimum is the solution of Program 2. As it maximizes welfare subject to informational constraints, it is by construction second best.

Lemma 2. *The planner's preferred allocation* $\{L^*, X^*, K^*, z^*, N_E^*, N_C^*\}$ *satisfies* $z = z[\kappa, F_X(X, N_C)] \leq z_0$ *from (13),* $L + X = 1$, $K = K_B$, $N_E = N$, $N_C = 1 - N$, *and*

$$F_X(X, N_C) = pR_L(L, N_E) - C(z) + C'(z) \underbrace{\lambda[F_X(X, N_C)\kappa - F_{XX}(X, N_C)(L - K)]}_{=-\left(\frac{\partial z}{\partial \kappa}\frac{\partial \kappa}{\partial L} - \frac{\partial z}{\partial r_D}\frac{dr_D}{dX}\right)L}. \tag{15}$$

The coefficient $\lambda \equiv (1 - p)/\nabla > 0$ *is proportional to the Jacobian determinant of incentive compatibility and participation constraints* ∇ *and is defined in Appendix A.1.*

Proof. See Appendix A.1. □

The loan portfolio is characterized by overspecialization, $z \leq z_0$. The reason is that the planner cannot control bank risk taking because of asymmetric information. The incentive compatibility constraint (12) suggests a more correlated portfolio as long as the bank is financed with debt (risk shifting). To mitigate this effect, investing the entire wealth of bankers in equity is optimal, giving $K = K_B$ and $\kappa = K_B/L$. All other things equal, more equity increases the capital ratio κ and thereby reduces costly overspecialization.

Optimal investment equalizes the social marginal products of capital across sectors, see (15). In the banking sector, the social marginal product is smaller than its first-best counterpart $pR_L(L, N_E) - C(z)$ because of two adverse incentive effects. First, more investment exacerbates risk shifting by lowering the capital ratio κ as aggregate equity is fixed. Second, expansion implies that the frictionless sector attracts less investment. The rising marginal return magnifies the opportunity costs of households who thus require a higher return on deposits, $r_D = F_X(X, N_C)$. Consequently, expansion of the banking sector simultaneously shifts the IC-curve in Fig. 1 to the left and the PC-curve up. The tighter constraints lead to a less diversified portfolio. Both effects are proportional to $C'(z) \leq 0$ because risk taking reduces welfare via specialization costs. They create a wedge between the sectoral returns to capital, $F_X(X, N_C) > pR_L(L, N_E) - C(z)$.[6]

Compared to the first best, capital allocation and risk taking change as follows:

Proposition 2. *Moral hazard causes smaller investment in the banking sector (i.e.,* $L^* < \tilde{L}$*) and less diversified loans portfolios (i.e.,* $z^* < \tilde{z} = z_0$*) leading to a higher risk of bank failure.*

Proof. See Appendix A.1. □

Banks overspecialize due to risk shifting. This diminishes their social marginal product relative to full information. Evaluating the central condition (15) at first-best values $\tilde{L}$ and $\tilde{X}$ reveals that the frictionless technology earns an excess return. Shifting investment towards this technology decreases its marginal return, while it increases the marginal product in the banking sector both directly and by improving risk-taking incentives.

Unlike in the first best, the banker earns an informational rent as the profit margin $pr_L - r_D = pR_L(L^*, N) - F_X(X^*, 1 - N)$ exceeds the specialization cost $C(z^*)$. It emerges because reallocating capital to the frictionless sector leads to higher loan and lower deposit rates. The latter reduce the debt burden of banks and mitigate risk shifting.

The first-best allocation could, in principle, be implemented despite asymmetric information if banks were financed only with equity, $\kappa = 1$. This would eliminate risk shifting altogether but can only be an equilibrium outcome if aggregate equity K_B is abundant.[7] This case is not empirically relevant, and the subsequent analysis thus focuses on scarce bank equity such that $\kappa < 1$.

3.4. Market equilibrium

This section derives the competitive market equilibrium under moral hazard.

3.4.1. Choices

Bankers: In the beginning, bankers choose loans L and equity K and promise investors a deposit rate b as to maximize their expected utility v^B. They take the loan rate r_L and the required return on deposits r_D as given. Subsequently, they choose portfolio diversification z according to (12) conditional on the capital ratio κ and deposit rate b.

The banker must satisfy participation and incentive compatibility constraints, (1) and (12). Deposit rate and portfolio diversification are thus implicit functions of the capital ratio and the required return on deposits, $z = z(\kappa, r_D)$ and $b = b(\kappa, r_D)$. Moreover, equity is constrained by the banker's private wealth K_B.

One can substitute (1) as well as the banker's subsequent risk-taking choice (13) into expected bank profit (2) to get the consolidated problem:

Program 3. The banker maximizes expected utility v^B by choosing loans L and equity K

$$v^B = \max_{L,K}[pr_L - r_D(1 - \kappa) - C(z(\kappa, r_D))]L + r_B(K_B - K) \tag{16}$$

subject to the capital availability constraint $K \leq K_B$. The banker anticipates subsequent risk-taking incentives, $z = z(\kappa, r_D)$, according to Lemma 1.

[6] The wedge is zero if the bank is all-equity financed, $\kappa = 1$, such that $z = z_0$ and $C'(z) = 0$, see (12). It becomes infinitely large as the capital ratio reaches the minimum for a feasible debt contract, $\kappa \to \kappa_0$, in which case $\nabla \to 0$ and $\lambda \to \infty$. According to (15), the marginal cost of expanding beyond $L = \kappa_0 K_B$, in which case no debt contract for the bank exists, is prohibitively high.

[7] Endowment of bankers must be such that the optimality condition (10) holds for $L = KB$, $F_X(1 - K_B, 1 - N) \leq pR_L(K_B, N) - C(z_0)$, and first-best investment in the banking sector is financed with equity only, $K_B \geq \tilde{L}$.

The bank extends loans until the marginal utility is zero:

$$pr_L - r_D - C(z) + C'(z)\underbrace{\lambda[z + (1-z)p]b\kappa}_{=-\frac{\partial z}{\partial \kappa}\frac{\partial \kappa}{\partial L}L} = 0. \tag{17}$$

Credit expansion increases expected utility proportional to the profit margin net of the effort costs, $pr_L - r_D - C(z)$. Moral hazard creates an additional cost represented by the last, negative term. Whenever a bank grants an additional loan, its capital ratio κ *ceteris paribus* declines thereby tightening the incentive compatibility constraint. This eventually exacerbates risk shifting and magnifies specialization costs.

The first-order condition for bank equity

$$\zeta = r_D - r_B - C'(z)\underbrace{\lambda[z + (1-z)p]b\kappa}_{=\frac{\partial z}{\partial \kappa}\frac{\partial \kappa}{\partial K}L} \tag{18}$$

pins down the multiplier of the capital availability constraint ζ. Investing in corporate bonds yields r_B, while investing in equity mechanically reduces debt and increases expected bank profit by $(z + (1-z)p)b$. In addition, the rising capital ratio improves risk-taking incentives, which is captured by the last term.

Firms and households: Corporate and entrepreneurial firms maximize (expected) profits, see (3) and (4). They choose investment and labor according to the standard first-order conditions $F_X(X, N_C) = r_B$ and $F_N(X, N_C) = w_C$ as well as $R_L(L, N_E) = r_L$ and $R_N(L, N_E) = w_E$, respectively.

Households finance both sectors if expected asset returns are the same, see (5). They inelastically supply labor N and $1-N$ to entrepreneurial and corporate firms.

3.4.2. Equilibrium

The competitive market equilibrium is a vector of choices $\{L^\circ, X^\circ, D^\circ, K^\circ, z^\circ N_E^\circ, N_C^\circ\}$ and contractual and market prices $\{b^\circ, r_B^\circ, r_D^\circ, r_L^\circ, w_E^\circ, w_C^\circ\}$ and the multiplier of the capital availability constraint ζ°. They satisfy the conditions for a deposit contract which is incentive-compatible and ensures participation of investors in (13), the first-order conditions (17) - (18) and the capital availability constraint of banks $K \le K_B$, the first-order conditions of firms following (3) - (4), no-arbitrage (5), and market clearing (7).

Noting no-arbitrage, $r_D = r_B$, Eq. (17) implies that bank equity earns an excess return compared to bonds. The capital availability constraint therefore binds (i.e., $\zeta > 0$), and the banker always invests the entire wealth as bank equity, $K = K_B$. The following lemma summarizes key properties of the market equilibrium:

Lemma 3. *Banks engage in risk shifting and overspecialize, $z^\circ = z(\kappa^\circ, r_D^\circ) \le z_0$, and the capital allocation equalizes private marginal products of capital across sectors*

$$pR_L(L, N_E) - C(z) + C'(z)\underbrace{\lambda F_X(X, N_C)\kappa}_{=-\frac{\partial z}{\partial \kappa}\frac{\partial \kappa}{\partial L}L} = F_X(X, N_C). \tag{19}$$

Proof. See Appendix A.1. □

The central condition (19) follows from combining bank's first-order condition (17) with no-arbitrage (5) and optimal investment of entrepreneurial and corporate firms following (3) - (4). The marginal product in the banking sector is equal to the return to capital $pR_L(L, N_E) - C(z)$ net of an adverse incentive effect: Since equity is fixed in equilibrium, credit expansion lowers the capital ratio κ thereby aggravating risk shifting. Unlike the planner, banks take the required return on deposits r_D as given and do not internalize that credit expansion raises borrowing costs thereby tightening the participation constraint and exacerbates risk shifting of all banks.

3.5. Pecuniary externality and misallocation

The market outcome differs from the constrained social optimum chosen by a welfare-maximizing regulator: Evaluating the central condition for sectoral investment (15) at the market values $X = X^\circ$ and $L = L^\circ$ implied by (19) reveals that capital in the frictionless sector earns an excess (social) return. Such differences in marginal products point to capital misallocation because shifting investment from entrepreneurial to corporate firms promises welfare gains: Starting from the market equilibrium, the marginal product of capital falls in the frictionless but rises in the banking sector as the higher capital ratio κ and lower borrowing cost r_D of banks improve their risk-taking incentives.

The following proposition summarizes the main distortions of the market outcome relative to the constrained social optimum:

Proposition 3. *Shifting capital from the banking to the frictionless sector (i.e., $X^* > X^\circ$ and $L^* < L^\circ$) increases social welfare provided that bank equity is scarce. In equilibrium, this raises the capital ratio (i.e., $\kappa^* > \kappa^\circ$) and lowers the borrowing costs of banks (i.e., $r_D^* < r_D^\circ$), which both lead to a better diversified loan portfolio (i.e., $z^* > z^\circ$) and a lower probability of bank failure.*

Proof. The market equilibrium differs from the planner's preferred allocation that maximizes constrained welfare by construction, see (15) and (19). Appendix A.1 proves $L^* < L^\circ$, which implies $X^* > X^\circ$. With fixed equity and labor, $K = K_B$ and $N_C = 1 - N$, this implies $\kappa^* > \kappa^\circ$ and $r_D^* > r_D^\circ$, leading to $z^\circ < z^*$ (Lemma 1). □

The source for these distortions is a pecuniary externality. Atomistic banks take the required return on deposits r_D as given. They ignore that attracting deposits and extending credit lowers corporate investment and thus increases the marginal product of capital in the frictionless sector. Because of no-arbitrage, the required return on deposits rises and the participation constraint is tighter. This equilibrium effect aggravates risk shifting of all banks (see Lemma 1), leading to higher failure risk and smaller welfare losses. Of course, a single bank does not influence equilibrium interest rates but the fact that all banks decide about deposits and ignore the price reaction causes an aggregate externality. Unlike in Gersbach and Rochet (2012, 2017), the externality is associated with the deposit interest rate instead of asset prices.

The pecuniary externality causes capital misallocation and excessive risk taking of banks. The two distortions are intertwined: The inefficiently large banking sector is the reason for the low capital ratio and the high borrowing costs, which exacerbate risk shifting. Asymmetric information is, in turn, the reason why risk taking of all banks is sensitive to their borrowing costs in the first place. Competitive banks ignore this equilibrium effect and attract too much funds thereby causing misallocation.

The pecuniary externality, first of all, rationalizes misallocation between different sectors. With some limitations, our finding is also consistent with within-sector misallocation across different firms that features more prominently in the literature (e.g., Gopinath et al., 2017). One may interpret the sectors as small, bank-dependent and large, market-financed firms, respectively.

Our result of overinvestment in the banking sector shares some similarities with models of the socially optimal capital structure of banks like Gersbach et al., 2015 or Britz et al. (2017), who find equilibria with overinvestment and excessive bank debt. However, our reasoning is fundamentally different: Overinvestment is driven by a pecuniary externality that rests on risk shifting and an inelastic deposit supply. In their model, it instead results from expectations about government bailouts of failed banks.

To explore the conditions under which the pecuniary externality is especially important, we analyze the wedge between social and private marginal products of the banking technology in

(15) and (18). It represents the equilibrium effect on risk taking via rising costs of deposits that is not internalized and causes the pecuniary externality.

Corollary 1. *The wedge between social and private marginal products of capital in the banking sector equals*

$$\varphi \equiv -C'(z)L\frac{\partial z}{\partial r_D}\frac{dr_D}{dX} = -\frac{\lambda(1-p)b(1-\kappa)}{\varepsilon_D} \le 0. \tag{20}$$

It is negative and the social marginal product is smaller than the private if there is moral hazard ($\lambda > 0$), bank equity is scarce ($\kappa < 1$), and the deposit supply is inelastic ($\varepsilon_D < \infty$).

Proof. The wedge φ follows from subtracting the private from the social marginal product of the banking technology in (15) and (18). We substitute the elasticity of the deposit supply $\varepsilon_D \equiv (\partial D/\partial r_D) \times r_D/D$ together with $r_D = F_X(X, N_C)$ and $D = L - K$, which implies $\partial D/\partial r_D = -1/F_{XX}(X, N_C)$ and $\varepsilon_D = -r_D/F_{XX}(X, N_C)D > 0$. □

The combination of (i) moral hazard, which renders risk taking sensitive to capital structure and borrowing costs, (ii) scarce equity, which forces banks to use debt, and (iii) an inelastic supply of deposits, which makes borrowing costs sensitive to the aggregate capital allocation, creates the wedge between private and social marginal products φ. It only disappears if one of these three frictions is absent, in which case a competitive market equilibrium would maximize constrained welfare.[8]

In general, this wedge is small if banks are well capitalized or the supply of deposits is elastic, $\varepsilon_D \to \infty$. In the latter case, credit expansion only has a weak effect on the borrowing costs. Capital ratio and supply elasticity are endogenous and, for example, depend on characteristics of the production function. Broadly speaking, the pecuniary externality thus matters the most if risk shifting is severe because of little equity and if deposits are inelastic such that the interest rate strongly responds to domestic investment. The latter is more plausible for large rather than small, open economies that borrow or lend on the international capital market at a constant rate.

Although this is a real model, one may suspect that the zero lower bound can affect this mechanism because the supply of deposits becomes very elastic at low interest rates. This renders the borrowing costs and, ultimately, risk taking less responsive to investment and diminishes the pecuniary externality. Through this specific channel, expansive monetary policy might contribute to reduced misallocation and bank risk taking.

4. Discussion

4.1. Macroprudential regulation

The analysis has identified a welfare-reducing pecuniary externality that exists in the absence of many typical frictions and institutional problems in banking like mis-priced deposit insurance, implicit guarantees or default costs. Macroprudential regulation can correct this distortion and implement the constrained social optimum. We consider two typical instruments: minimum capital requirements and deposit rate ceilings (e.g., Regulation Q). Since the regulator must fulfill incentive compatibility and participation constraints, it suffices to set the capital ratio or the contractual deposit rate accordingly:

Corollary 2. *The constrained social optimum can be implemented in a market economy by minimum capital requirements $\kappa \ge \kappa^*$ or a deposit rate ceiling $b \le b^*$.*

Proof. The banker solves Program 3 subject to the regulatory constraint. Appendix A.1 demonstrates that the constraint binds and the market equilibrium coincides with the constrained social optimum. □

Intuitively, the deposit rate b must be kept at an artificially low level compared to the market to mitigate risk shifting. This can be achieved either by limiting bank leverage and deposit demand with capital requirements or by direct price control. This equivalence result, at first sight, contrasts with Hellmann et al. (2000), who consider capital requirements less effective in mitigating risk shifting than deposit rate controls because costly equity depresses future profits and charter value. However, both instruments are equivalent in a purely static context.

An alternative approach is redistributing wealth from households to bankers. Such an ex ante transfer raises constrained welfare because it increases available bank equity.[9] Hence, banks can improve their capital ratio and risk-taking incentives without reducing credit or expand without exacerbating risk shifting. A large transfer would allow for all equity-financed banks, which eliminates risk shifting altogether, and thus even implement the first best. The latter should, however, be cautiously interpreted as the model abstracts from positive effects of bank debt (e.g., liquidity services).

While ex ante transfers may appear quite attractive in principle, they would involve fundamental changes to the banking system and require tools that are non-standard for regulators. The positive welfare effect of ex ante redistribution should rather be understood as supporting policies that aim at making bank equity more available (e.g., addressing the debt bias in corporate taxation or improving investor protection).

4.2. Comparative statics

A macroprudential regulator takes the economic environment into account when setting capital requirements or deposit rate ceiling. The latter are endogenous and equal to the values, κ^* and b^*, that follow from constrained welfare maximization for given parameters (see, Corollary 2).

We assume that regulation implements the constrained social optimum and study how two key parameters of the model affect equilibrium: aggregate bank equity K_B and the productivity of entrepreneurial firms A. The comparative statics analysis informs about how macroprudential regulation should be adjusted to changes in these parameters that fluctuate over the business cycle and feature prominently in the literature on countercyclical bank regulation (e.g., Repullo, 2013; Malherbe, 2015).

We focus on scarce bank equity such that $\kappa < 1$ and $K = K_B$. Notation is as follows: dx indicates absolute and $\hat{x} = dx/x$ percentage changes. Since labor is fixed in equilibrium, $N_E = N$ and $N_C = 1 - N$, we use the shortcuts $R(L) \equiv R(L, N)$ and $F(X) \equiv F(X, 1 - N)$. Eventually, we make two assumptions:

Assumption 6. The production function of entrepreneurial firms is $R(L) = Ar(L)$ with productivity parameter A and $r'(L) > 0 > r''(L)$. Management costs are quadratic, $C(z) = 0.5c(z - z_0)^2$, with $C'(z) = c(z - z_0)$ and $C''(z) = c$.

Risk taking: Portfolio diversification z increases in the capital ratio κ and decreases in the required return on deposits r_D (see Lemma 1). The reverse is true for the risk-adjusted deposit rate b. Capital ratio and required return on deposits are endogenous and satisfy $L \cdot d\kappa = dK_B - \kappa \cdot dL$ as well as $dr_D = dr_B = F''(X) \cdot dX$ on ac-

[8] If risk taking was contractible or equity abundant, the market outcome would be first best.

[9] The positive welfare effect follows from an Envelope argument in Program 2, giving $dW/dK = \zeta > 0$.

count of no-arbitrage. Noting $dX = -dL$, risk taking adjusts according to

$$dz = \lambda_K \cdot \hat{K}_B - \lambda_L \cdot \hat{L} \quad (21)$$

with both elasticities being positive

$$\lambda_K \equiv \lambda\kappa[z + (1-z)p]b, \quad \lambda_L \equiv \lambda\left[(z + (1-z)p)b\kappa - F''(X)(L - K_B)\right]$$

and satisfying $\lambda_L > \lambda_K$. Larger aggregate equity and smaller loans lead to more diversified portfolios. The former because the higher capital ratio relaxes the incentive compatibility constraint, the latter by increasing the capital ratio and lowering the required return r_D.

The risk-adjusted deposit rate (1), in turn, adjusts according to $[z + (1-z)p] \cdot db = dr_D - (1-p)b \cdot dz$. After substituting (21) for dz and $dr_D = F'(X) \cdot dL$, one observes that it rises with bank credit and decreases in aggregate equity:

$$[z + (1-z)p] \cdot db = -(1-p)b\lambda_K \cdot \hat{K}_B + [-F''(X)L + (1-p)b\lambda_L] \cdot \hat{L}. \quad (22)$$

Capital allocation: In constrained social optimum, investment equalizes the social marginal products of the two sectors, see (15). Using the coefficient λ_L defined following (21), one can express the optimality condition as:

$$F'(X) = pR'(L) - C(z) + \lambda_L C'(z). \quad (23)$$

The elasticity λ_L captures direct and indirect incentive effects of additional investment in the banking sector. Appendix A.2 linearizes this expression step by step, uses $dX = -dL$, $dR = R(L) \cdot \hat{A} + R'(L)L \cdot \hat{L}$ as well as (21), and finally yields:

$$\hat{L} = \sigma_A \cdot \hat{A} + \sigma_K \cdot \hat{K}_B. \quad (24)$$

Both elasticities defined in (Appendix A.18) in Appendix A.2 are positive. Consequently, entrepreneurial firms increase investment whenever bank equity K_B is more available or their productivity A rises. Intuitively, more equity alleviates risk shifting and thus increases the marginal product of capital in the banking sector, which thus expands. Similarly, higher sectoral productivity boosts the marginal return $pR'(L)$ and renders larger investment in the banking sector optimal. In both cases, investment of corporate firms falls proportionately, $\widehat{X} = -\hat{L}$.

Macroprudential regulation: A regulator who imposes minimum capital requirements $\kappa^* = K_B/L^*$ responds according to $\hat{\kappa}^* = \hat{K}_B - \hat{L}$ or, after substituting (24), $\hat{\kappa}^* = (1-\sigma_K) \cdot \hat{K}_B - \sigma_A \cdot \hat{A}$. First, capital requirements are relaxed if the banking technology becomes (relatively) more productive: Since aggregate equity is fixed, a smaller capital ratio is necessary for more investment of bank-dependent, entrepreneurial firms. Second, Eq. (Appendix A.19) in Appendix A.2 verifies $\sigma_K < 1$, and capital requirements are tightened if bank equity becomes more available.

The deposit rate ceiling b^*, in turn, changes according to (22). After substituting for $\hat{L}$, one obtains $[z + (1-z)p] \cdot db^* = [(-F''(X)L\sigma_K + (1-p)b(\lambda_L\sigma_K - \lambda_K)] \cdot \hat{K}_B + [-F''(X) + (1-p)b\lambda_L]\sigma_A \cdot \hat{A}$. Clearly, the cap should be increased if entrepreneurial firms become more productive. The response to aggregate equity can be of either sign: On the one hand, banks take fewer risks and can offer a lower interest rate. On the other hand, investment shifts from corporate to entrepreneurial firms such that the former are more profitable at the margin and offer a higher bond return. Households thus require a higher expected return on deposits as well.

Regulators should respond to economic shocks in a nuanced fashion and, for instance, adjust capital requirements procyclically to variations in aggregate equity but countercyclically to variations in productivity. If a downturn is primarily characterized by a shortage of equity ('capital crunch), it is optimal to relax capital requirements. If instead bank-dependent firms become (relatively) less productive, regulators should tighten them. This mirrors prior findings in the literature on the cyclical adjustment of capital regulation (e.g., Repullo, 2013; Malherbe, 2015). This nuanced policy allows entrepreneurial firms to expand if the economic environment improves, see (24), without undermining risk-taking incentives of banks. A cap on deposit rates, in turn, should be adjusted procyclically to productivity but its adjustment to aggregate equity can be of either sign.

Welfare: Eventually, changes in aggregate equity or sectoral productivity affect social welfare, $W = F(X) + pR(L) - C(z)L$, see Program 3. Applying the Envelope theorem implies $dW/dK_B = \zeta = -C'(z)\lambda b[z + (1-z)p]/L > 0$ and $dW/dA = pr(L) > 0$. The multiplier ζ is positive as scarce equity mitigates risk shifting. Redistributing wealth from households to bankers ex ante thus improves welfare because banks are ultimately better capitalized, which mitigates risk shifting and misallocation. Higher productivity of entrepreneurial firms is welfare-improving irrespective of risk shifting.

4.3. Distributional implications

Macroprudential regulation that addresses the pecuniary externality increases social welfare, which is desirable from a utilitarian point of view. How does this policy affect the distribution of utility across bankers and households and is it a Pareto improvement? Regulation shifts investment from entrepreneurial to corporate firms, which discourages risk shifting of banks by lowering their borrowing costs. This reallocation of capital also diminishes asset returns from r_D° to r_D^* and affects labor productivity and wages in both sectors. These effects largely determine the distributional consequences:

Corollary 3. *Macroprudential regulation is no Pareto improvement: It increases utility of bankers but reduces aggregate household income. Effects on households are heterogeneous: While all households earn a smaller capital income, labor income of those who work in the corporate (frictionless) sector rises (falls).*

Proof. Noting no-arbitrage (5), expected returns on deposits and bonds decline, $r_B^* < r_B^\circ$ and $r_D^* < r_D^\circ$, due to $X^* > X^\circ$. Since labor and capital are complements, the wage in the frictionless sector rises, $w_C^* = F_N(X^*, 1-N) > F_N(X^\circ, 1-N) = w_C^\circ$, due to the higher capital intensity. As $L^* < L^\circ$, the wage in the banking sector thus falls, $w_E^* = R_N(L^*, N) < R_N(L^\circ, N) = w_E^\circ$. Appendix A.1 shows that regulation leads to smaller aggregate household income π^H. Since the macroprudential regulation implements the welfare-maximizing allocation, bankers' expected utility necessarily rises. □

The induced changes in interest rates increase banks' profit margin.[10] In addition, banks choose a more diversified portfolio with smaller specialization costs. These two effects boost bankers' utility although the loan volume shrinks.

However, macroprudential regulation diminishes aggregate income of households π^H: The decline in asset returns r_D and r_B hurts all households. The effect on labor income is asymmetric, however: Corporate firms attract more capital, which renders labor more productive. Households who work in this sector benefit thus from a rising wage w_C, which tends to offset the adverse effect of declining capital income. In contrast, bank-dependent entrepreneurial firms receive less credit. Their lower capital intensity diminishes labor productivity and wage w_E. Households who work

[10] This larger informational rent is consistent with the idea of financial restraint defined by Hellmann et al. (1997) as a set of policies that increase rent opportunities in the private sector (compared to a competitive benchmark) to alleviate informational frictions.

for such firms thus experience a decrease in both capital and labor income.

This finding suggests that a utilitarian regulator who aims at maximizing social welfare will always internalize the pecuniary externality. A more conservative regulator who restricts herself to Pareto improvements over the market outcome may, in contrast, decide not to implement such regulations. More generally, the proof of Corollary 3 also implies that aggregate household income is always lower than in market equilibrium as soon as investment is shifted from the banking to the frictionless sector. Hence, households overall are worse off in all allocations which a regulator can implement with the available instruments minimum capital requirements and deposit rate ceilings. The market outcome can thus be considered constrained Pareto efficient as any feasible intervention makes at least some households worse off although it may increase utilitarian welfare.

However, some caveats remain: With exogenous savings, households can only adjust the composition of their savings but not the volume. In a dynamic model, they would save less if returns decline. The same holds true for the inelastic labor supply. Moreover, banks are typically reluctant to accept regulatory interventions especially tighter capital standards. How can one reconcile this behavior with the view that banks may even benefit from regulation in terms of larger rents? On the one hand, regulation addresses only one particular distortion in our analysis, namely, the pecuniary externality. Other distortions (e.g., contagion, bankruptcy costs) may well justify even tighter capital requirements, and total bank profits may eventually decline if investment in the banking sector falls more strongly. On the other hand, we do not consider any shareholder-manager conflicts: Managers might enjoy private benefits proportional to bank size like prestige. Their private surplus could thus be reduced when bank size is constrained.

5. Conclusion

This paper reconsiders the risk-shifting problem of banks and analyzes how it affects the allocation of capital in the economy at large. It establishes three main results: (i) A welfare-reducing pecuniary externality causes capital misallocation and excessive bank risk taking in competitive market equilibrium: Banks ignore how their choices affect the aggregate allocation of capital, which, in turn, influences borrowing costs and risk-taking incentives of all other banks. Compared to a constrained social optimum, the banking sector is inefficiently large and overly indebted and banks take excessive risks. (ii) This distortion provides a novel rationale for macroprudential regulation independent of many typical frictions (e.g., guarantees, mis-priced priced deposit insurance, bankruptcy costs). The pecuniary externality can be internalized with capital requirements and deposit rate ceilings. These instruments constrain the size of the banking sector, lower borrowing costs, and magnify informational rents of banks in order to reduce risk taking. (iii) Macroprudential regulation is not a Pareto improvement, however. It diminishes asset returns of households and wages paid by bank-dependent firms but benefits banks and raises wages paid by market-financed firms.

CRediT authorship contribution statement

Michael Kogler: Conceptualization, Formal analysis, Investigation, Methodology, Visualization, Writing - original draft, Writing - review & editing.

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Appendix A

A1. Proofs and derivations

Proof of Lemma 1. Portfolio diversification z and the risk-adjusted deposit rate b are jointly determined by the constraints (1) and (12). The Jacobian matrix is

$$J = \begin{bmatrix} C''(z) & (1-p)(1-\kappa) \\ (1-p)b & z+(1-z)p \end{bmatrix} \tag{A.1}$$

with the determinant

$$\nabla = C''(z)[z+(1-z)p] - (1-p)^2 b(1-\kappa) > 0. \tag{A.2}$$

The positive sign can be shown graphically: In Fig. 1, the IC-curve has to be steeper than the PC-curve in the intersection point because (i) both constraints give rise to a negative, monotonic relation between b and z and (ii) IC suggests $b = 0$ for $z = z_0 < 1$, while PC is convex (i.e., $d^2b/dz^2 > 0$) and suggests $b = r_D \geq 0$ for $z = 1$. Implicitly differentiating (1) and (12) yields the slopes, which must satisfy

$$\frac{db}{dz}_{|IC} = -\frac{C''(z)}{(1-p)(1-\kappa)} < -\frac{(1-p)b}{z+(1-z)p} = \frac{db}{dz}_{|PC}. \tag{A.3}$$

Rearranging this inequality gives (Appendix A.2) and assures $\nabla > 0$. As long as a feasible contract exists (i.e., IC- and PC-curves intersect), this property holds. Otherwise when $\kappa \to \kappa_0$ such that IC and PC are tangent and the slopes in (Appendix A.3) are the same, the determinant converges to zero, $\nabla \to 0$.

Finally, we apply Cramer's rule and define $\lambda \equiv (1-p)/\nabla > 0$ to get the sensitivities:

$$\frac{\partial z}{\partial \kappa} = \lambda b[z+(1-z)p] > 0, \quad \frac{\partial z}{\partial r_D} = -\lambda(1-\kappa) \leq 0,$$
$$\frac{\partial b}{\partial \kappa} = -\lambda(1-p)b^2 < 0, \quad \frac{\partial b}{\partial r_D} = \frac{\lambda C''(z)}{1-p} > 0. \tag{A.4}$$

□

Proof of Lemma 2. Denoting the multipliers of resource and capital availability constraints by μ, η^i, and ζ, the first-order conditions are

$$\frac{\partial W}{\partial L} = pR_L(L, N_E) - C(z) - C'(z)L\frac{\partial z}{\partial \kappa}\frac{\partial \kappa}{\partial L} - \mu = 0,$$
$$\frac{\partial W}{\partial X} = F_X(X, N_C) - C'(z)L\frac{\partial z}{\partial r_D}\frac{dr_D}{dX} - \mu = 0,$$
$$\frac{\partial W}{\partial K} = -C'(z)L\frac{\partial z}{\partial \kappa}\frac{\partial \kappa}{\partial K} - \zeta = 0,$$
$$\frac{\partial W}{\partial N_E} = pR_N(L, N_E) - \eta^E = 0,$$
$$\frac{\partial W}{\partial N_C} = F_N(X, N_C) - C'(z)L\frac{\partial z}{\partial r_D}\frac{dr_D}{dN_C} - \eta^C = 0,$$

and the constraints. From (Appendix A.4), we know $\partial z/\partial \kappa = \lambda b[z+(1-z)p]$ and $\partial z/\partial r_D = -\lambda(1-\kappa)$ and $\lambda = (1-p)/\nabla > 0$.

Capital ratio and interest rate change according to:

$$\frac{\partial \kappa}{\partial L} = -\frac{\kappa}{L}, \quad \frac{\partial \kappa}{\partial K} = \frac{1}{L}, \quad \frac{dr_D}{dX} = \frac{dr_D}{dr_B}\frac{dr_B}{dX} = F_{XX}(.),$$
$$\frac{dr_D}{dN_C} = \frac{dr_D}{dr_B}\frac{dr_B}{dN_C} = F_{XN}(.).$$

Combining the first-order conditions for L and X, substituting for the sensitivities, and rearranging gives (15). Noting that $C'(z) = -(1-p)b(1-\kappa) \leq 0$ on account of (12), the first-order condition for K implies $\zeta = -C'(z)\lambda b[z + (1-z)p]/L > 0$ such that the capital availability constraint binds, $K = K_B$, as long as $\kappa < 1$.

Eventually, the first constraint on labor always binds, giving $N_E = N$. The second constraint typically binds as well despite a counteracting second-order effect. The latter emerges because additional labor N_C renders capital more productive the frictionless sector (due to complementarity), which ultimately leads to higher borrowing costs of banks and exacerbates risk shifting. We henceforth focus on production and cost functions and labor endowment which ensure that the direct, positive welfare effect of labor input prevails such that $\eta^C > 0$ and $N_C = 1 - N$. □

Proof of Proposition 2. Banks overspecializes, $z < z_0 = \tilde{z}$, because of moral hazard as implied by the incentive compatibility constraint (12).

To show that optimal investment shifts from banking to the frictionless sector, we use the shortcuts $R'(L) \equiv R_L(L, N)$ and $F'(X) \equiv F_X(X, 1-N)$ as labor is fixed and note that investment satisfies $F'(X^*) < pR'(L^*) - C(z^*)$ in the constrained social optimum and $F'(\widetilde{X}) = pR'(\widetilde{L}) - C(z_0)$ in the first best, see (10) and (15).

We demonstrate $L^* < \widetilde{L}$ and $X^* > \widetilde{X}$ by contradiction: First, suppose $L^* > \widetilde{L}$ and $X^* < \widetilde{X}$. This implies $F'(X^*) > F'(\widetilde{X})$ and $pR'(L^*) - C(z^*) < pR'(\widetilde{L}) - C(z_0)$ due to diminishing magical returns and specialization costs caused by risk shifting, $C(z^*) > C(z_0)$. Because of (15), the following inequalities hold:

$$F'(X^*) < pR'(L^*) - C(z^*) < pR'(\widetilde{L}) - C(z_0) = F'(\widetilde{X}). \tag{A.5}$$

They are inconsistent with our conjecture $X^* < \widetilde{X}$ due to the concavity of $F(X)$.

Second, suppose $L^* = \widetilde{L}$ and $X^* = \widetilde{X}$. Again, $pR'(L^*) - C(z^*) < pR'(\widetilde{L}) - C(z_0)$ holds due to risk shifting such that

$$F'(X^*) < pR'(L^*) - C(z^*) < pR'(\widetilde{L}) - C(z_0) = F'(\widetilde{X}). \tag{A.6}$$

These inequalities violate $X^* = \widetilde{X}$. Therefore, investment has to be smaller in the banking and larger in the frictionless sector, $L^* < \widetilde{L}$ and $X^* > \widetilde{X}$. □

Proof of Lemma 3. Denoting the multiplier of the capital availability constraint by ζ, the first-order conditions of Problem 3 are

$$\frac{\partial v^B}{\partial K} = r_D - r_B - C'(z)L\frac{\partial z}{\partial \kappa}\frac{\partial \kappa}{\partial K} - \zeta = 0,$$
$$\frac{\partial v^B}{\partial L} = pr_L - r_D - C(z) - C'(z)L\frac{\partial z}{\partial \kappa}\frac{\partial \kappa}{\partial L} = 0,$$

as well as $\zeta(K_B - K) = 0$. After substituting $\partial z/\partial\kappa = \lambda[z + (1-z)p]b$ as well as $\partial\kappa/\partial K = 1/L$ and $\partial\kappa/\partial L = -\kappa/L$ into the first two equations, one obtains (17) - (18).

Since no-arbitrage holds in equilibrium, Eq. (17) implies $\zeta > 0$ such that $K = K_B$ on account of complementary slackness.[11] □

Proof of Proposition 3. Again, use $R'(L) \equiv R_L(L, N)$ and $F'(X) \equiv F_X(X, 1-N)$. We show $L^* < L^\circ$ by contradiction: Starting with $L^* \geq L^\circ$, it follows that $X^* \leq X^\circ$ and $F'(X^*) = r_D^* \geq r_D^\circ = F'(X^\circ)$. The capital ratio is also smaller, $\kappa^* \leq \kappa^\circ$, due to $K^* = K^\circ = K_B$. Lemma 1 thus implies $z^* \leq z^\circ$.

Noting the optimality conditions (15) and (19), the following inequality must hold:

$$\begin{aligned} F'(X^*) &= pR'(L^*) - C(z^*) + C'(z^*)\lambda^*\big[F'(X^*)\kappa^* - F''(X^*)(L^* - K_B)\big] \\ &\geq p[R'(L^\circ)C(z^\circ) + C'(z^\circ)\lambda^\circ F'(X^\circ)\kappa^\circ = F'(X^\circ). \end{aligned} \tag{A.7}$$

We rearrange this condition:

$$\begin{aligned} &-C'(z^\circ)\lambda^\circ F'(X^\circ)\kappa^\circ + C'(z^*)\lambda^*\big[F'(X^*)\kappa^* - F''(X^*)(L^* - K_B)\big] \\ &\geq p[R'(L^\circ) - R'(L^*)] - [C(z^\circ) - C(z^*)] \geq 0. \end{aligned} \tag{A.8}$$

The right-hand side of the inequality is nonnegative as $L^* \geq L^\circ$ implies (i) $R'(L^*) \leq R'(L^\circ)$ and (ii) $\kappa^* \leq \kappa^\circ$ and $r_D^* \geq r_D^\circ$ such that $z^* \leq z^\circ$ and $C(z^*) \geq C(z^\circ)$. Noting $C'(z) \leq 0$ and $-F''(X^*) > 0$, condition (Appendix A.8) necessarily requires that the sum of the first two terms is positive, $-C'(z^\circ)\lambda^\circ F'(X^\circ)\kappa^\circ + C'(z^*)\lambda^* F'(X^*)\kappa^* > 0$. After substituting (12) and (Appendix A.5) for $C'(z) = -(1-p)b(1-\kappa)$ and λ, one obtains:

$$\lambda^* b^*(1-\kappa^*)F'(X^*)\kappa^* < \lambda^\circ b^\circ(1-\kappa^\circ)F'(X^\circ)\kappa^\circ. \tag{A.9}$$

Given the conjecture $L^* \geq L^\circ$, the term $\lambda b(1-\kappa)F'(X)\kappa$ must decrease in L. However, this is generally not true: The ratio is zero for $L \leq K_B$, which implies $\kappa = 1$, and it diverges to infinity for any $L \to \min\{\kappa_0 K_B, 1\}$ when either no feasible financing contract exists (i.e., $\lambda \to \infty$) or borrowing becomes prohibitively expensive. Consequently, condition (Appendix A.7) is inconsistent with $L^* \geq L^\circ$. □

Proof of Corollary 2. We add the regulatory constraint $\kappa \geq \kappa^*$ to the banker's problem (Program 3) and get the Lagrangian:

$$\mathcal{L} = [pr_L - r_D(1-\kappa) - C(z)]L + r_B(K_B - K) + \zeta[K_B - K] + \psi[\kappa - \kappa^*]. \tag{A.10}$$

The Kuhn-Tucker conditions are:

$$\frac{\partial \mathcal{L}}{\partial K} = r_D - r_B - \left[C'(z)L\frac{\partial z}{\partial \kappa} - \psi\right]\frac{\partial \kappa}{\partial K} - \zeta = 0,$$
$$\frac{\partial \mathcal{L}}{\partial L} = pr_L - r_D - C(z) - \left[C'(z)L\frac{\partial z}{\partial \kappa} - \psi\right]\frac{\partial \kappa}{\partial L} = 0,$$
$$\frac{\partial \mathcal{L}}{\partial \psi} = \kappa - \kappa^* \geq 0, \quad \frac{\partial \mathcal{L}}{\partial \psi}\psi = \psi(\kappa - \kappa^*) = 0.$$

If the regulatory constraint did not bind, $\kappa > \kappa^*$, complementary slackness would require $\psi = 0$. The Kuhn-Tucker conditions coincide with those of the unregulated market equilibrium, giving $\kappa = \kappa^\circ$ (see, proof of Proposition 3). Since $\kappa^* > \kappa^\circ$, however, this outcome violates the regulatory constraint, which is therefore binding, $\kappa = \kappa^*$. The binding capital availability constraint $K = K_B$ implies $L = L^*$ and $X = X^*$. Together with $r_D^* = F_X(X^*, 1-N)$, the capital ratio κ^* assures $z = z^*$.

Whenever the regulator imposes a deposit rate ceiling $b \leq b^*$, the regulatory constraint is added to the banker's optimization problem. Using a similar argument as above, the banker always chooses $b = b^*$. From Fig. 1, one may conclude that several pairs $\{\kappa, r_D\}$ satisfy IC and PC for $b = b^*$. However, only κ^* and r_D^* are consistent with the investment decision of corporate firms. Suppose the bank's capital ratio is slightly higher, $\kappa > \kappa^*$. The incentive compatibility implies a more diversified portfolio as the IC-curve in Fig. 1 shifts up. At the same time, bank size must fall because investment shifts to corporate firms. This depresses the bond return and relaxes the participation constraint (i.e., the PC-curve shifts down). As a result, the intersection of the two constraints implies $b < b^*$. The deposit rate ceiling would be slack but

[11] To see this, substitute $r_B = r_D$ in (17) and get $\zeta = -C'(z)\lambda[z + (1-z)p]b\kappa$. ζ depends the capital ratio κ and is equal to 0 if $\kappa = 1$ such that $z = z_0$ and strictly positive otherwise. Hence, only $K = K_B$ and $K = L$ are consistent with complementary slackness. If $K = L$, $z = z_0$, the condition (19) coincides with the first best giving $L = \widetilde{L}$. This can only be true if aggregate equity satisfies $K_B \geq \widetilde{L}$. Otherwise, we have $K = K_B < L$, which implies $\kappa < 1$ and $z < z_0$ and eventually $\zeta > 0$.

the banker would never choose this because her optimal choice is $b^\circ = b^*$. □

Proof of Corollary 3. We need to show that aggregate household income, $\pi^H = r_D D + r_B(V-D) + pw_E N + w_C(1-N)$, is smaller under macroprudential regulation than in the unregulated market equilibrium. Zero firm profits imply:

$$w_E N = R(L,N) - r_L L, \quad w_C(1-N) = F(X, 1-N) - r_B X. \tag{A.11}$$

Together with bond market clearing, $X = V - D$, one can rewrite aggregate household income as $\pi^H = r_D D + F(X, 1-N) + p[R(L,N) - r_L L]$.

Starting with $X^* > X^\circ$ and $L^* < L^\circ$, we proceed in two steps and first demonstrate $r_D^* D^* + F(X^*, 1-N) < r_D^\circ D^\circ + F(X^\circ, 1-N)$. Using the shortcut $F'(X) \equiv F_X(X, 1-N)$ and noting $r_D^* = F'(X^*, 1-N) \le F'(X^\circ) = r_D^\circ$ as well as $D = V - X$, we get

$$\begin{aligned} r_D^\circ D^\circ - r_D^* D^* &> F(X^*) - F(X^\circ) \\ r_D^\circ D^* + r_D^\circ (D^\circ - D^*) - r_D^* D^* &> F(X^*) - F(X^\circ) \\ r_D^\circ D^* + r_D^\circ (X^* - X^\circ) - r_D^* D^* &> \textstyle\int_{X^\circ}^{X^*} F'(x)dx \\ \left(r_D^\circ - r_D^*\right) D^* + F'(X^\circ)(X^* - X^\circ) &> \textstyle\int_{X^\circ}^{X^*} F'(x)dx. \end{aligned} \tag{A.12}$$

The last expression is equal to

$$(r_D^\circ - r_D^*)D^* + \int_{X^\circ}^{X^*} F'(X^\circ) - F'(x)dx > 0, \tag{A.13}$$

which is positive due to $r_D^\circ > r_D^*$ and $F'(X^\circ) > F'(x)$ for all $x > X^\circ$.

Next, we show that labor income of households who work for entrepreneurial firms is smaller under macroprudential regulation, $p[R(L^*, N) - r_L^* L^*] < p[R(L^\circ, N) - r_L^\circ L^\circ]$. Using the shortcut $R'(L) \equiv R_L(L, N)$ and $R'(L) = r_L$, one obtains:

$$\begin{aligned} r_L^\circ L^\circ - r_L^* L^* &< R(L^\circ, N) - R(L^*, N) \\ r_L^\circ (L^\circ - L^*) - (r_L^* - r_L^\circ) L^* &< R(L^\circ, N) - R(L^*, N) \\ R'(L^\circ)(L^\circ - L^*) - (r_L^* - r_L^\circ) L^* &< \textstyle\int_{L^*}^{L^\circ} R'(l)dl \\ -(r_L^* - r_L^\circ) L^* &< \textstyle\int_{L^*}^{L^\circ} R'(l) - R'(L^\circ)dl. \end{aligned} \tag{A.14}$$

Recall that $L^* < L^\circ$ and that the marginal product of capital decreases. Therefore, the right-hand side is positive because $R'(l) > R'(L^\circ)$ for all $l < L^\circ$. The left-hand side is, in contrast, negative because of $r_L^* = R'(L^*) > R'(L^\circ) = r_L^\circ$.

Since both components of π^H are smaller under macroprudential regulation compared to an unregulated market equilibrium, aggregate household income is smaller as well. □

A2. Comparative statics

Capital allocation: Differentiating (23) and using $dX = -dL$ gives:

$$-\left[F''(X)L + pR''(L)L\right] \cdot \hat{L} = pAr'(L) \cdot \hat{A} - [C'(z) - C''(z)\lambda_L] \cdot dz + C'(z) \cdot d\lambda_L.$$

Substituting $dz = \lambda_K \cdot \hat{K}_B - \lambda_L \cdot \hat{L}$ gives:

$$\begin{aligned} &-\left[F''(X)L + pR''(L)L + c((z - z_0) - \lambda_L)\lambda_L\right] \\ &\cdot \hat{L} = pR'(L) \cdot \hat{A} + c(z - z_0) \cdot d\lambda_L \\ &\quad - c[(z - z_0) - \lambda_L]\lambda_K \cdot \hat{K}_B \end{aligned} \tag{A.15}$$

which uses $R'(L) = Ar'(L)$ and the functional form $C(z) = 0.5c(z - z_0)^2$. The effects importantly depend on λ_L, which summarizes all incentive effects associated with credit expansion, see (21). Differentiating this expression gives

$$\begin{aligned} d\lambda_L = &\lambda_L \cdot \hat{\lambda} + \lambda[(1-p)b\kappa \cdot dz + (z + (1-z)p)(\kappa \cdot db + b \cdot d\kappa)] \\ &- \lambda F''(X)(dL - dK) - \lambda F'''(X)(L - K_B) \cdot dX \end{aligned} \tag{A.16}$$

with $\hat{\lambda} \equiv d\lambda/\lambda = -(1/\nabla) \cdot d\nabla$. We henceforth assume that $F'''(X)$ is nonnegative, which is true for most concave production functions. Noting our parametric assumptions, the determinant satisfies $d\nabla = (1-p)c \cdot dz - (1-p)^2(1-\kappa) \cdot db + (1-p)^2 b \cdot d\kappa$. After substituting for db from above and rearranging, this simplifies to $d\nabla = 2(1-p)c \cdot dz$, giving $\hat{\lambda} = -2(1-p)c/\nabla \cdot dz = -2\lambda c \cdot dz$. Next, we substitute for dz and db in (Appendix A.16) and use $(1-p)b\kappa \cdot dz + (z + (1-z)p) \cdot db = -F''(X) \cdot dX$:

$$\begin{aligned} d\lambda_L = &-2\lambda_L \lambda c \cdot dz + \lambda[F''(X)\kappa \cdot dX + (z + (1-z)p)b \cdot d\kappa] \\ &- \lambda F''(X)(dL - dK_B) - \lambda F'''(X)(L - K_B) \cdot dX. \end{aligned}$$

Using $dX = -dL$ and $(z + (1-z)p)b = F'(X)$ and differentiating $\kappa = K_B/L$, one gets:

$$\begin{aligned} d\lambda_L &= -2\lambda_L \lambda c \cdot dz + \lambda\kappa[F'(X) + F''(X)L] \cdot \hat{K}_B \\ &\quad + \lambda[-F'(X)\kappa - F''(X)(1+\kappa)L + F'''(X)(1-\kappa)L^2] \cdot \hat{L} \\ &= \lambda\left[\kappa(F'(X) + F''(X)L) - 2\lambda_L \lambda_K c\right] \cdot \hat{K}_B \\ &\quad + \lambda[-F'(X)\kappa - F''(X)(1+\kappa)L + F'''(X)(1-\kappa)L^2 + 2\lambda_L^2 c] \cdot \hat{L}. \end{aligned}$$

We note $\lambda F'(X)\kappa = \lambda_K$ and rewrite this expression as

$$d\lambda_L = -[\lambda\bar{\sigma}_K - \lambda_K] \cdot \hat{K}_B + [\lambda\bar{\sigma}_L - \lambda_K] \cdot \hat{L} \tag{A.17}$$

with both coefficients defined positive

$$\begin{aligned} \bar{\sigma}_K &\equiv -F''(X)\kappa L + 2\lambda_L \lambda_K c, \\ \bar{\sigma}_L &\equiv -F''(X)(1+\kappa)L + F'''(X)(1-\kappa)L^2 + 2\lambda_L^2 c. \end{aligned}$$

Note that they satisfy $\bar{\sigma}_L > \bar{\sigma}_K$. We finally substitute (Appendix A.17) for $d\lambda_L$ in (Appendix A.15), rearrange, and get:

$$\hat{L} = \sigma_A \cdot \hat{A} + \sigma_K \cdot \hat{K}_B \tag{A.18}$$

with coefficients

$$\sigma_K \equiv -\frac{c[-(z - z_0)\lambda\bar{\sigma}_K + \lambda_L \lambda_K]}{F''L + pR''L - c\lambda_L^2 + c(z - z_0)(\lambda\bar{\sigma}_L + \lambda_L - \lambda_K)} > 0,$$

$$\sigma_A \equiv -\frac{pR'(L)}{F''L + pR''L - c\lambda_L^2 + c(z - z_0)(\lambda\bar{\sigma}_L + \lambda_L - \lambda_K)} > 0.$$

This formulation uses the shortcuts $F'' = F''(X)$ and $R'' = R''(L)$. Under the restriction that $F'''(X)$ is nonnegative, both coefficients are unambiguously positive due to the concavity of $F(X)$ and $R(L)$, overspecialization in constrained equilibrium $z < z_0$, and $\lambda_L > \lambda_K$ on account of (21).

Macroprudential regulation: To show that capital requirements increase in aggregate equity, $\hat{\kappa}^* = \hat{K}_B - \hat{L} = (1 - \sigma_K) \cdot \hat{K}_B$, we need to verify $1 > \sigma_K$ or, after substitution,

$$\begin{aligned} 1 - \sigma_K &= \frac{F''L + pR''L - c\lambda_L(\lambda_L - \lambda_K) + c(z - z_0)(\lambda(\bar{\sigma}_L - \bar{\sigma}_K) + \lambda_L - \lambda_K)}{F''L + pR''L - c\lambda_L^2 + c(z - z_0)(\lambda\bar{\sigma}_L + \lambda_L - \lambda_K)} \\ &> 0. \end{aligned} \tag{A.19}$$

Both numerator and denominator are negative due to the concavity of $R(L)$ and $F(X)$ and $z < z_0$, $\lambda_L > \lambda_K$, and $\bar{\sigma}_L > \bar{\sigma}_K$, see (21) and (Appendix A.18).

References

Allen, F., Gale, D., 2000. Comparing financial systems. MIT Press, Cambridge and London.
Allen, F., Gale, D., 2004. Competition and financial stability. Journal of Money, Credit and Banking 36(3), 453–480.
Beck, T., De Jonghe, O., Schepens, G., 2013. Bank competition and stability: cross-country heterogeneity. Journal of Financial Intermediation 22(2), 218–244.
Beck, T., Demirgüç-Kunt, A., Levine, R., 2006. Bank concentration, competition and crisis: first results. Journal of Banking and Finance 30(5), 1581–1612.
Boyd, J.H., De Nicoló, G., 2005. The theory of bank risk taking and competition revisited. Journal of Finance 60(3), 1329–1343.
Britz, V., Gersbach, H., Haller, H., 2017. Deposit Insurance and Reinsurance: A General Equilibrium Perspective. CEPR Discussion Paper No. 11947.

Davila, E., Korinek, A., 2018. Pecuniary externalities in economies with financial frictions. Review of Economic Studies 85, 352–395.
Demsetz, R.S., Saidenberg, M.R., Strahan, P.E., 1996. Banks with something to lose: the disciplinary role of franchise value. Economic Policy Review 2, 1–14.
Gersbach, H., Haller, H., Müller, J., 2015. The macroeconomics of Modigliani-Miller. J. Econ. Theory 157, 1081–1113.
Gersbach, H., Rochet, J.-C., 2012. Aggregate investment externalities and macroprudential regulation. Journal of Money, Credit and Banking 44(2), 73–109.
Gersbach, H., Rochet, J.-C., 2017. Capital regulation and credit fluctuations. J. Monet. Econ. 90, 113–124.
Gopinath, G., Kalemli-Özcan, S., Karabarbounis, L., Villegas-Sanches, C., 2017. Capital allocation and productivity in South Europe. Quarterly Journal of Economics 132(4), 1915–1967.
Greenwald, B.C., Stiglitz, J.E., 1986. Externalities in economies with imperfect information and incomplete markets. Quarterly Journal of Economics 101(2), 229–264.
Hakenes, H., Schnabel, I., 2011. Capital regulation, bank competition, and financial stability. Econ. Lett. 113, 256–258.
Hellmann, T.F., Murdock, K.C., Stiglitz, J.E., 1997. Financial Restraint: Towards a New Paradigm. In: Aoki, M., Kim, H.-K., Okuno-Fujiwara, M. (Eds.), The Role of Government in East Asian Economic Development: Comparative Institutional Analysis. Clarendon, Oxford, pp. 163–207.
Hellmann, T.F., Murdock, K.C., Stiglitz, J.E., 2000. Liberalization, moral hazard in banking, and prudential regulation: are capital requirements enough? American Economic Review 90(1), 147–165.
Hsieh, C.-T., Klenow, P., 2009. Misallocation and manufacturing TFP in China and India. Journal of Quarterly Economics 124(4), 1403–1448.
Jiménez, G., Lopez, J., Saurina, J., 2013. How does competition affect bank risk-taking? Journal of Financial Stability 9(2), 185–195.
Keeley, M.C., 1990. Deposit insurance, risk and market power in banking. American Economic Review 80(5), 1183–1200.
Lorenzoni, G., 2008. Inefficient credit booms. Review of Economic Studies 75(3), 809–833.
Malherbe, F., 2015. Optimal Capital Requirements Over the Business and Financial Cycles. ECB Working Paper No. 1830.
Martinez-Miera, D., Repullo, R., 2010. Does competition reduce the risk of bank failure? Review of Financial Studies 23(10), 3638–3664.
Reis, R., 2013. The Portuguese slump and crash and the Euro crisis. Brookings Pap. Econ. Act. 44(1), 143–210.
Repullo, R., 2004. Capital requirements, market power, and risk-taking in banking. Journal of Financial Intermediation 13(2), 452–490.
Repullo, R., 2013. Cyclical adjustment of capital requirements: asimple framework. Journal of Financial Intermediation 22(3), 608–626.
Rochet, J.-C., 1992. Capital requirements and the behaviour of commercial banks. Eur. Econ. Rev. 36(5), 1137–1178.
Salas, V., Saurina, J., 2003. Deregulation, market power and risk-behaviour in Spanish banks. Eur. Econ. Rev. 47, 1061–1075.
Tressel, T., Verdier, T., 2014. Optimal Prudential Regulation of Banks and the Political Economy of Supervision. CEPR Discussion Paper, No. 9871.
Suarez, J., Sussman, O., 1997. Endogenous cycles in a Stiglitz-Weiss economy. J. Econ. Theory 76(1), 47–71.
Wurgler, J., 2000. Financial markets and the allocation of capital. J. financ. econ. 58(1–2), 187–214.