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## Saving Wall Street or main street

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Markus Haavio – Antti Ripatti – Tuomas Takalo

# **Saving Wall Street or Main Street**



Bank of Finland Research  
Discussion Paper  
12 • 2016

# Saving Wall Street or Main Street\*

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## Abstract

We build a dynamic stochastic general equilibrium model, where the balance sheets of both banks and non-financial firms play a role in macro-financial linkages. We show that in equilibrium bank capital tends to be scarce, compared with firm capital. We study public funding of banks and firms in times of crisis. Government capital injections can be useful as a shock cushion, but they distort incentives. Small capital injections benefit banks more than firms but the relative benefit is declining in the injection size. Government should first recapitalize banks, and if resources are large enough, lend to firms too.

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# 1 Introduction

Governments' capital injections to the banking system and direct public funding of non-financial firms have been important tools in attempts to support credit flows during financial crises. In the crisis episodes that took place over the period 1970 to 2007, government capitalization of banks averaged around eight percent of GDP (Laeven and Valencia, 2012). These resolution measures were present in 33 crisis episodes out of 42. During the Great Recession, government capital injections to banks were close to five percent in the US (SIGTARP, 2014).<sup>1</sup> The Federal Reserve System extended its funding programs to non-financial firms, while the US Treasury provided direct financing to the auto industry. The peak of the outstanding assets of the FED programmes for non-banks reached almost three percent of GDP (Labonte, 2016). In March 2016, the Eurosystem extended its asset purchase programme to include bonds issued by non-financial corporations.<sup>2</sup>

In this paper, we analyze and compare bank capitalization and direct public funding to non-financial firms in times of crisis. The key question we ask is the following: Suppose the government has decided to provide funding to the private sector. How should the money be allocated? Should the government target (only) banks or (only) non-financial firms, or maybe both? Our main result establishes a pecking order of public interventions: the government should first capitalize banks, but if the scale of public funding is large enough, the marginal dollar should be lent directly to non-financial firms.

We analyze these issues using a dynamic stochastic general equilibrium (DSGE) model with financial frictions, where balance sheets of both banks

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<sup>1</sup>In Europe the recapitalization measures reached 38 percent in Ireland, 19 percent in Greece and 10 percent in Cyprus (EU Commission, 2014). In the US, the Capital Purchase Program (CPP) of TARP, and its' follower CAP, injected capital in the form of preferred shares. Citigroup, AIG and GMAC/Ally got government capital in the form of common equity.

<sup>2</sup>General Motors and Chrysler got direct support from Treasury. The FED created Commercial Paper Funding Facility (CPFF) and Term Asset-Backed Securities Loan Facility (TALF) programs. These programmes aimed to provide liquidity to the securitization market and to non-financial firms respectively. The Eurosystem's bond purchases are part of the programme that initially included only government bonds.

and non-financial firms play a role in macro-financial linkages. Our framework builds on the Holmstrom and Tirole (1997) model of financial intermediation.<sup>3</sup> In the DSGE models building on Holmstrom and Tirole (1997)<sup>4</sup> entrepreneurs and banks can leverage their investments by using external funding, but this leverage creates moral hazard problems. Hence sufficiently large banks' and entrepreneurs' own stakes in the projects are needed to maintain their incentives, which implies that the aggregate amount of informed capital (sum of bank capital and entrepreneurial wealth) in the economy plays a crucial role in the propagation of shocks. In this framework, however, quantitative implications of bank capital cannot easily be disentangled from those of entrepreneurial wealth. These models also require a bank's asset portfolio to be completely correlated, so that deposits (or short-term debt) cannot be genuinely distinguished from (outside) bank equity.<sup>5</sup>

We extend the DSGE framework building on Holmstrom and Tirole (1997) to allow for the separate roles of bank capital and entrepreneurial wealth, on the one hand, and bank equity and bank deposits, on the other hand. There are several novel features in our model: First, as in the simultaneously written paper by Christensen, Meh and Moran (2011), we allow monitoring investments to be continuous: the more the banks invest in costly monitoring, the lower the entrepreneurs' private benefits from unproductive projects but the less the banks can lend. This feature implies that the banks monitoring investments vary over the business cycle and that not only the aggregate amount of informed — bank and firm — capital but also its compo-

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<sup>3</sup>While earlier models of macro-financial linkages (notable examples include Kiyotaki and Moore 1997, Carlstrom and Fuerst 1997, and Bernanke, Gertler and Gilchrist 1999) typically focused on the balance sheets of non-financial firms and treated financial intermediation as a veil, in recent years an increasing number of macro models with banks has been developed, notable examples include Gertler and Karadi (2010) and Gertler and Kiyotaki (2011). However, many of these new generation macro-banking models abstract from the balance sheets of non-financial firms. The Holmstrom – Tirole (1997) framework is attractive in the sense that it allows the simultaneous analysis of both banks' balance sheets and the balance sheets of non-financial firms.

<sup>4</sup>Aikman and Paustian (2006), Faia (2010) and Meh and Moran (2010) use Holmstrom – Tirole (1997) framework in macroeconomic models. Early attempts include Castrén and Takalo (2000) and Chen (2001).

<sup>5</sup>If the projects in the bank's asset portfolio succeed, all parties, both debt and equity holders, get their due share of the proceeds. If the projects fail, nobody gets anything.

sition matters in the propagation of shocks. Second, we distinguish between bankers and banks. In our model, a bank is a balance sheet entity with a capital structure but only a banker faces an incentive problem. This is not only realistic but also allows us to relax the assumption of a completely correlated investment portfolio of a bank; as a result deposits can be meaningfully distinguished from bank equity. The distinction between bankers and banks is also instrumental when we introduce an aggregate investment shock, which plays a key role in our model. Finally, we strive to benchmark our model to the standard Real Business Cycle model, which requires a number of subtle but important changes to the previous macro literature building on Holmstrom and Tirole (1997).

The key results of the modelling effort are the following: i) In equilibrium bank capital is scarce in the sense that the ratio of bank capital to entrepreneurial wealth is lower than that which would maximize the investments and output. Also, a given change in bank capital affects aggregate investments more than an equal proportional change of entrepreneurial wealth. ii) Bank capital is more vulnerable to aggregate investment shocks than is entrepreneurial capital. iii) Given properties i) and ii), bank capital plays a more important role in the propagation of investment shocks and in macroeconomic dynamics than does entrepreneurial capital.

Our model forms an attractive framework for studying government involvement in banks and in non-financial firms. Since bank capital is more important in macroeconomic dynamics, bank capitalization provides a more effective way to stabilize the economy than direct public funding of non-financial firms. This is the case in particular when the size of public programs is small or moderate: given the scarcity of bank capital and high bank leverage, capital injections initially have a (very) large proportional effect on banks' shock cushions. However, due to the scarcity of bank capital, public funds also blunt incentives and distort the economy more when placed in banks than when placed in non-financial firms. Weighing the social benefits (enhanced stability) and social costs (blunted incentives), we establish a pecking order of public interventions: the government should first capitalize banks, but if the scale of public programs is large enough, it should extend

funding to non-financial firms.

To our knowledge, the literature studying both bank and firm funding in a unified framework is very scarce. Gertler and Kiyotaki (2011) is a notable exception. They study credit market interventions that were introduced in the wake of the financial crisis. Without comparing the interventions, they show that the net benefits of these interventions are increasing with the severity of the crisis. There is a sizable literature on bank recapitalizations and bailouts. Philippon and Schnabl (2013) study forms of efficient recapitalizations while Bhattacharya and Nyborg (2013) use the menu of bailout plans as a screening device. In these papers, banks suffer from debt-overhang. Therefore, these papers differ from ours in approach and model. Gertler and Karadi (2011, 2013), Curdia and Woodford (2011), and Del Negro et al (2011) study large scale (private) asset purchases by the central bank, which can be interpreted as direct government funding of non-financial firms. The asset purchases mitigate disruptions in asset substitution in a financial crisis environment. Our paper contributes to the literature by providing a utility-based comparison of bank capitalization and direct public lending to non-financial firms, in a framework where the balance sheets of both banks and non-financial firms matter and the social costs and benefits of public policies arise in a natural way.

In the next section we describe the basic model. In Section 3 we explain why bank capital is scarce in equilibrium. In Section 4 we introduce an investment shock into the model, and discuss the distinction between bankers and banks. In Section 5 we study the impulse responses of financial and macro variables to a number of shocks. In Section 6 we analyse capital injections and direct lending from the government to banks and firms. Section 7 concludes.

## 2 The Model

We consider a discrete time, infinite horizon economy populated by households with three types of members: workers, entrepreneurs, and bankers. In the financial side of the economy, bankers manage financial intermediaries

(banks) that obtain deposits from households and finance entrepreneurs. The real economy contains two sectors: i) competitive firms producing final goods from labour supplied by workers and capital supplied by entrepreneurs, and ii) entrepreneurs producing capital goods.

Households own banks and all firms, including those producing capital goods. The production of capital is subject to a dual moral hazard problem in the sense of Holmstrom and Tirole (1997): First, entrepreneurs, who may obtain external finance from households and banks, are tempted to choose less productive projects with higher non-verifiable returns. Second, bankers' monitoring can mitigate the entrepreneurs' moral hazard temptations, but since banks use deposits from households to finance entrepreneurs, there is an incentive to shirk in costly monitoring.

## 2.1 Households

Following Gertler and Karadi (2011) we assume that there is a continuum of identical households of measure unity. Within each household, there are three occupations: in every period  $t$ , a fraction of the household members become entrepreneurs, another fraction become bankers, and the rest remain workers. After each period, an entrepreneur and a banker exit from their occupations at random according to a Poisson processes with constant exit rates  $1 - \lambda^e$ ,  $\lambda^e \in (0, 1)$ , and  $1 - \lambda^b$ ,  $\lambda^b \in (0, 1)$ , respectively. In a steady state the number of household members becoming entrepreneurs and bankers equals the number of exiting entrepreneurs and bankers.

The head of a household decides on behalf of its members how much to work, consume, and invest in capital. In Section 2.4 we explain in detail how entrepreneurs invest in risky projects to produce capital goods and how bankers provide funding for these investments. In general, entrepreneurs and bankers earn higher returns on their risky investments than workers earn on their deposits. Hence it is optimal for the household to let its entrepreneurs and bankers keep building up their assets until exiting their occupations. The exiting entrepreneurs and bankers give their accumulated assets to the household which in turn provides new entrepreneurs and bankers with some



initial investment capital. Within a household there is perfect consumption insurance against the risks of entrepreneurs and bankers. Therefore, all household members consume an equal amount in each period.

The problem of a representative household is

$$\max_{\{C_t \geq 0, L_t \geq 0, K_t \geq 0\}_{t=0}^{\infty}} E_0 \left[ \sum_{t=0}^{\infty} \beta^t \left( \frac{1}{1-\sigma} C_t^{1-\sigma} - \frac{\xi}{1+\phi} L_t^{1+\phi} \right) \right], \quad (1)$$

subject to a budget constraint:

$$C_t + q_t K_{t+1} + T_t = W_t L_t + K_t [r_t^K + q_t(1-\delta)]. \quad (2)$$

In the household's utility function (1),  $\xi > 0$ ,  $\phi > 0$  and  $\sigma \in (0, 1)$  are parameters,  $\beta \in (0, 1)$  is the rate of time preference, and  $C_t$  and  $L_t$  denote consumption and hours worked in period  $t$ , respectively. In the budget constraint (2),  $T_t$  denotes lump-sum transfers (net payouts from entrepreneurs and bankers),  $W_t$  real wage,  $K_t$  is the stock of physical capital,  $r_t^K$  the real rental price of capital,  $q_t$  is the price of capital goods and, finally,  $\delta \in (0, 1)$  is the rate of depreciation of physical capital. Note that we assume, as in Carlstrom and Fuerst (1997), that bank deposits are intra-period deposits. They can, consequently, be excluded from the intertemporal budget constraint (2). While being somewhat controversial, this assumption facilitates comparison of our model with the standard RBC framework.

Physical capital stock accumulates according to the law of motion

$$K_{t+1} = (1-\delta)K_t + p_H R I_t, \quad (3)$$

where  $I_t$  is investment in period  $t$ . This accumulation equation is standard save for the two parameters of capital good production,  $p_H \in (0, 1)$  and  $R \geq 1$ , which will be defined more precisely in Section 2.4.

Solving the household's dynamic optimization problem yields the familiar first order conditions for  $L_t$  and  $K_{t+1}$ , respectively:

$$\frac{\xi L_t^\phi}{C_t^{-\sigma}} = W_t \quad (4)$$

and

$$q_t = \beta E_t \left\{ \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma} [r_{t+1}^K + q_{t+1}(1 - \delta)] \right\}. \quad (5)$$

## 2.2 Final Good Production

Competitive firms in the final good sector combine capital  $K_t$  and labor  $L_t$  using the Cobb-Douglas production function

$$Y_t = K_t^\alpha (Z_t L_t)^{1-\alpha}, \quad (6)$$

where  $\alpha \in (0, 1)$ , and  $Z_t$  is the common labor-augmenting technology. Profit maximization results in the familiar equations for the optimality condition:

$$W_t = (1 - \alpha) \frac{Y_t}{L_t} \quad (7)$$

$$r_t^K = \alpha \frac{Y_t}{K_t}. \quad (8)$$

## 2.3 Production of Capital

Capital demanded by firms in the final good sector is produced by entrepreneurs who are endowed with investment projects and some initial wealth. Entrepreneurs can also attempt to leverage their investments by borrowing from bankers and workers. It may be best to think that intermediation of entrepreneurial finance occurs only among households. To clarify how financial intermediation takes place, let us consider three households, A, B, and C. We can either think that the workers of household A invest their funds directly in projects of household C's entrepreneurs, along with the capital from the banks of household B, or that the workers of household A first deposit their funds with the banks of household B, who then invest the deposits in projects of household C's entrepreneurs along with their own bank capital. For clarity of presentation, we work with the latter interpretation.

All successful investment projects transform  $i$  units of final goods into

$Ri$  ( $R > 1$ ) verifiable units of capital goods while failed projects yield nothing. The projects differ in their probability of success and in the amount of non-verifiable revenues then create. There is a "good" project that is successful with probability  $p_H$  and involves no non-verifiable revenues to the entrepreneur.

There is also a continuum of bad projects with common success probability  $p_L$  ( $0 \leq p_L < p_H < 1$ ) but with differing amounts of non-verifiable revenues  $bi$ ,  $b \in (0, \bar{b}]$ , attached to them. Non-verifiable revenues are proportional to investment size as in Holmstrom and Tirole (1997).<sup>6</sup> But departing from Holmsröm and Tirole (1997), where bad projects generate non-transferable private benefit, we assume — like Meh and Moran (2010), Faia (2010), and Christiansen et al. (2012) — that private benefits are divisible and transferable.<sup>7</sup> In our case this assumption is only needed to ensure the smoothness of out-of-equilibrium payoffs: If, in an out-of-equilibrium event, an entrepreneur had picked a bad project, her project returns should be transferable and divisible among her household members upon her exit from entrepreneurship. Further, we assume that  $q_t p_H R > \max \{1, q_t p_L R + \bar{b}\}$  to ensure that the good project i) has a positive rate of return and ii) is preferable to all bad projects from the household's point of view.

Bankers are endowed with a variable-scale monitoring technology that enables them to constrain the entrepreneurs' project choice. Monitoring at the intensity level  $m$  ( $m \geq 0$ ) eliminates all bad projects where  $b \geq b(m)$  from the entrepreneur's project choice set. The threshold level of non-verifiable revenues  $b(m)$  is decreasing and convex in monitoring intensity:  $b'(m) \leq 0$ ,  $b''(m) \geq 0$ , and  $\lim_{m \rightarrow \infty} b'(m) = 0$ . As in Christiansen et al. (2012) monitoring consumes real resources (e.g., labor): to obtain monitor-

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<sup>6</sup>In contrast, Meh and Moran (2010), Faia (2010), and Christiansen et al. (2012) assume that the non-verifiable revenues of bad projects are proportional to the value of capital goods. Making such an assumption would not qualitatively affect our results.

<sup>7</sup>One interpretation is, reminiscent of Bolton and Scharfstein (1990), that project revenues are verifiable outside a household only up to  $R$ , or that only revenues in terms of capital goods are verifiable outside a household. Alternatively, following, e.g., Burkart, Gromp, and Panunzi (1998), we may think that an entrepreneur is able to divert part of her firm's resources to her own use at an interim stage. As in Burkart et al. (1998), such expropriation of outside investors is costly, which is here captured by the lower expected project returns in the case of diversion takes place.

ing intensity  $m$ , a bank must pay  $mi$  units of final goods to workers. That is, the more a banker invests in monitoring, the less his bank can lend to entrepreneurs.

Because of diminishing returns to monitoring investments, the banker will never want to eliminate all bad projects. Therefore, despite monitoring, entrepreneurs must be provided with incentives to choose the good project. In sum, there are two moral hazard problems facing the households: one between bankers and entrepreneurs (borrowers), and another between bankers and workers (depositors). The moral hazard problems may be solved by designing a proper financing contract.

### 2.3.1 The Financing Contract

In each period  $t$ , there are three contracting parties: entrepreneurs, bankers, and depositors (workers). Following the standard practice we assume limited liability and inter-period anonymity, and focus on the class of one-period optimal contracts where entrepreneurs invest all their own wealth  $n_t$  in their projects. The financial contract then stipulates how much of the required funding of the project of size  $i_t$  comes from banks ( $a_t$ ) and depositors ( $d_t$ ) and how the project's return  $R$ , in case of success, is distributed among the entrepreneur ( $R_t^e$ ), her bankers ( $R_t^b$ ), and depositors ( $R_t^w$ ).

A banker, given his share of project returns, maximizes the bank's profits by choosing monitoring intensity,  $m_t$ . Banks behave competitively. As a result, they offer the same contract that would be offered by a single bank, which would maximize the entrepreneur's expected profits. An optimal financing contract therefore solves the following program:

$$\max_{\{i_t, a_t, d_t, R_t^e, R_t^b, R_t^w, m_t\}} q_t p_H R_t^e i_t$$

subject to the entrepreneur's and her banker's incentive constraints,

$$q_t p_H R_t^e i_t \geq q_t p_L R_t^e i_t + b(m_t) i_t, \quad (9)$$

$$q_t p_H R_t^b i_t \geq q_t p_L R_t^b i_t + (1 + r_t^d) m_t i_t, \quad (10)$$

the depositors' and banker's participation constraints,

$$q_t p_H R_t^w i_t \geq (1 + r_t^d) d_t, \quad (11)$$

$$q_t p_H R_t^b i_t \geq (1 + r_t^a) a_t, \quad (12)$$

and two resource constraints on investment inputs and outputs

$$a_t + d_t - m_t i_t \geq i_t - n_t, \quad (13)$$

$$R \geq R_t^e + R_t^b + R_t^w. \quad (14)$$

Equations (13) and (14) mean that the aggregate supply of investment funds must satisfy their aggregate demand equation and that the total returns must be enough to cover the total payments, respectively. Variable  $r_t^a$  featured in the banker's participation constraint (12), denotes the rate of return on bank capital in period  $t$  and, similarly, variable  $r_t^d$  in the banker's incentive constraint (10) and in the depositors' participation constraint (11), is the rate of return on deposits in period  $t$ . These rates of return will be determined as part of equilibrium.

It is clear that the entrepreneur wants to invest as much as possible, i.e., she wants to raise as much funds from outside as possible without breaking the depositors' and banker's participation and incentive constraints. Hence all constraints bind in equilibrium. Using these standard equilibrium properties, we solve the entrepreneur's program in two steps. First, we take the intensity of monitoring  $m_t$  and, by implication, the level of private revenues  $b(m_t)$  as given and solve for the maximum size of the investment project  $i_t$  for a given level of entrepreneurial wealth  $n_t$ . Secondly, we solve for the equilibrium level of monitoring  $m_t$ .

### 2.3.2 Investment and Leverage at the Project Level

In the Holmstrom-Tirole framework the maximum investment size depends on how much funds can be raised from outside, which in turn depends on how much of the project returns can credibly be pledged to depositors. In

Appendix A.1 we show that maximum investment size is

$$i_t = \frac{n_t}{g(r_t^a, r_t^d, q_t, m_t)}, \quad (15)$$

where

$$g(r_t^a, r_t^d, q_t, m_t) = \frac{p_H}{\Delta p} \left( \frac{b(m_t)}{1 + r_t^d} \right) + \left[ 1 + \frac{p_H}{\Delta p} \left( 1 - \frac{1 + r_t^d}{1 + r_t^a} \right) \right] m_t - \rho_t \quad (16)$$

is the inverse degree of leverage, i.e., the smaller the value of  $g(\cdot)$ , the larger the size of the investment project  $i_t$  for a given level of entrepreneurial wealth  $n_t$ . The first term on the right-hand side of equation (16) shows how agency problems in the non-financial firm reduce leverage by discouraging participation by outside investors. These agency problems can be mitigated by increasing the monitoring. However, the second term shows how more intense monitoring also has two negative effects on leverage since it consumes resources that could otherwise have been invested in the project and makes it harder to satisfy the banker's incentive constraint. These two effects are captured by the first and second terms in square brackets, respectively (note that in equilibrium we must have  $r_t^a \geq r_t^d$ ). In other words, more extensive monitoring activity worsens the agency problem between a bank and a depositor. To overcome this moral hazard and attract more deposits, a larger share of the investment project should be financed by bank capital. Finally, the term  $\rho_t \equiv p_H q_t R / (1 + r_t^d) - 1 > 0$  denotes the net rate of return on the good investment project; the larger the rate of return, the easier it is to attract outside funding.

### 2.3.3 Monitoring at the Project Level

Given the competitively behaving banking sector, the optimal choice of  $m_t$  maximizes the entrepreneur's expected profits  $p_H q_t R_t^e i_t$ , which may be rewritten, by using equations (9) and (15), as  $(p_H / \Delta p) b(m_t) n_t / g(r_t^a, r_t^d, q_t, m_t)$ .

Therefore the optimal level of monitoring solves the problem

$$\max_{m_t \geq 0} \frac{b(m_t)}{g(r_t^a, r_t^d, q_t, m_t)}. \quad (17)$$

As can be seen from equations (16) and (17) the effects of monitoring on the entrepreneur's expected payoff are complex. The denominator in the problem (17) shows how a larger scope of extracting private revenues implies a larger equilibrium share of the project returns for the entrepreneur, which dilutes the monitoring incentives (recall that the point of view is that of the entrepreneur). Monitoring incentives are also adversely affected by the negative effects of monitoring costs on leverage (second term in  $g(\cdot)$  in equation (16)). However, smaller agency problems enable larger leverage (first term in  $g(\cdot)$  in equation (16)). This provides an incentive for monitoring.

To derive a tractable analytic solution to problem (17), we specify the following functional form for  $b(m_t)$  :

$$b(m_t) = \begin{cases} \Gamma m_t^{-\frac{\gamma}{1-\gamma}} & \text{if } m_t > \underline{m} \\ \bar{b} & \text{if } m_t \leq \underline{m}, \end{cases} \quad (18)$$

where  $\Gamma > 0$ ,  $\bar{b} > 0$ ,  $\gamma \in (0, 1)$ , and  $\underline{m} \geq 0$ . The first row of equation (18) shows how  $b(m_t)$  is differentiable and strictly convex for  $m_t > \underline{m}$  and that the monitoring technology is the more efficient, the larger the value of  $\gamma$  or the smaller the  $\Gamma$ . The second row implies that there is a minimum efficient scale for monitoring investments or an upper bound for the private revenues. This upper bound ensures that a bad project has a lower rate of return than a good project even for low levels of  $m_t$ .<sup>8</sup>

Under the minimum scale requirement, the entrepreneur may choose a corner solution with no monitoring  $m_t = 0$ ,  $b(m_t) = \bar{b}$ , or a unique interior solution  $m_t = m_t^*$ . In the appendix we determine the conditions under which we can rule out the corner solution. These conditions are met around the steady state, on which we focus on in this paper. After substitution of

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<sup>8</sup>Naturally, we have experimented with many other functional forms besides specification (18), without gaining additional insights or simpler expressions.

equations (16) and (18) we can write the unique interior solution to the entrepreneur's problem (17) as

$$m_t^* = \frac{\gamma \rho_t}{1 + \frac{p_H}{\Delta p} \left(1 - \frac{1+r_t^d}{1+r_t^a}\right)}. \quad (19)$$

The optimal level of monitoring intensity characterized by equation (19) has intuitive properties: It is increasing in the elasticity of monitoring technology (directly related to  $\gamma$ ) and in the rate of return on the good project ( $\rho_t$ ). Also, the larger the negative effects of monitoring on leverage (which are in the denominator), the lower the optimal level of monitoring.

## 2.4 Aggregation

We proceed under the assumption that all projects will be monitored with the intensity given by equation (19) and, as a result, all entrepreneurial firms have the same capital structure. That is, for all projects, the ratios  $a_t/i_t$ ,  $d_t/i_t$ , and  $n_t/i_t$  are the same (The project sizes may nonetheless differ: the larger the entrepreneur's wealth  $n_t$ , the larger her investment  $i_t$ ). Given this symmetry, moving from project level to economy-wide level in terms of capital structures is simple. Clearly,

$$\frac{a_t}{i_t} = \frac{A_t}{I_t}, \quad \frac{d_t}{i_t} = \frac{D_t}{I_t}, \quad \text{and} \quad \frac{n_t}{i_t} = \frac{N_t}{I_t}. \quad (20)$$

where capital letters stand for aggregate level variables.

The economy-wide equivalent to monitoring intensity can be found by combining (20) with the banker's incentive and participation constraints (10) and (12). This gives

$$m_t^* = \frac{\Delta p}{p_H} \frac{1 + r_t^a}{1 + r_t^d} \frac{A_t}{I_t}. \quad (21)$$

Since in equilibrium the monitoring intensity given by equation (21) must be



equal to the one in equation (19), we have

$$1 + r_t^{a*} = (1 + r_t^d) \frac{\left(1 + \gamma \rho_t \frac{I_t}{A_t}\right)}{1 + \frac{\Delta p}{p_H}}. \quad (22)$$

For equation (22) to characterize the equilibrium rate of return on bank capital, it must hold that

$$r_t^{a*} > r_t^d. \quad (23)$$

Otherwise,  $r_t^{a*} = r_t^d$ . We proceed under the assumption that inequality (23) holds, verifying that the assumption is fulfilled later in equilibrium.

Next, by (15) and (20), inverse firm leverage satisfies the equation  $N_t/I_t = g(r_t^a, r_t^d, q_t, m_t)$ , where  $g(r_t^a, r_t^d, q_t, m_t)$  is given by (16). Plugging in the rate of return to bank capital (22), the equilibrium monitoring intensity (21) and the monitoring technology (18) yields after some algebra

$$\left(\frac{A_t}{I_t^*} + \gamma \rho_t\right)^\gamma \left(\frac{N_t}{I_t^*} + (1 - \gamma) \rho_t\right)^{1-\gamma} = \left(\frac{\Gamma}{(1 + r_t^d)} \frac{p_H}{\Delta p}\right)^{1-\gamma} \left(1 + \frac{p_H}{\Delta p}\right)^\gamma \quad (24)$$

Equation (24) implicitly determines the aggregate investment level  $I_t^*$  in the economy. Finally (13) and (20) imply that aggregate deposits in the banking system are given by

$$D_t = (1 + m_t^*) I_t - (A_t + N_t). \quad (25)$$

The aggregate investment level is part of a simple aggregate resource constraint:

$$Y_t = C_t + I_t. \quad (26)$$

Note from equation (26) that while monitoring consumes real resources in our model, it is assumed to consume no aggregate resources; as explained in Section 2.3, monitoring involves a transfer of final goods from banks to workers, and is hence included in the lump-sum transfers  $T_t$  in the household's budget constraint (2).

Aggregate capital good stock simply evolves according to equation (3).

However, it is also important to determine the evolution of bank and entrepreneurial capital. After the investment projects are realized, surviving entrepreneurs and bankers receive the proceeds from the sales of capital goods to capital rental firms so that the aggregate amount of final goods held by entrepreneurs and bankers at the end of period  $t$  are  $\lambda^e p_H R_t^e I_t$  and  $\lambda^b p_H R_t^b I_t$ , respectively (recall that  $\lambda^e$  and  $\lambda^b$  are the entrepreneur's and banker's survival probabilities). The value of a unit of undepreciated capital good at the beginning of period  $t + 1$  is  $(1 - \delta) q_{t+1}$ . Furthermore, the surviving entrepreneurs and bankers receive rental income  $r_{t+1}^K$  from the capital rental firms they own. As a result, the aggregate amount of capital held by bankers at the beginning of period  $t + 1$  is given by

$$A_{t+1} = [r_{t+1}^K + q_{t+1} (1 - \delta)] \lambda^b p_H R_t^b I_t, \quad (27)$$

which can be combined with conditions (12) and (20) to obtain the following law of motion for the aggregate bank capital:

$$A_{t+1} = \frac{A_t \lambda^b (1 + r_t^a) [r_{t+1}^K + (1 - \delta) q_{t+1}]}{q_t}. \quad (28)$$

Similarly, the law of motion of aggregate entrepreneurial capital is given by

$$N_{t+1} = [r_{t+1}^K + q_{t+1} (1 - \delta)] \lambda^e p_H R_t^e I_t, \quad (29)$$

which we can rewrite as

$$N_{t+1} = \frac{N_t \lambda^e (1 + r_t^e) [r_{t+1}^K + (1 - \delta) q_{t+1}]}{q_t} \quad (30)$$

where

$$1 + r_t^e \equiv q_t p_H R_t^e I_t / N_t = (1 + r_t^d) \left( 1 + (1 - \gamma) \rho_t \frac{I_t}{N_t} \right) \quad (31)$$

denotes the rate of return on entrepreneurial capital.

## 2.5 Equilibrium

Since in our model deposits occur within a period, they carry no interest rate, i.e.,  $r_t^d = 0$ . In addition to  $r_t^d = 0$ , an equilibrium of the economy is a time path

$$\{K_{t+1}, L_t, q_t, Y_t, W_t, r_t^K, m_t, I_t, C_t, A_{t+1}, N_{t+1}\}_{t=0}^{\infty}$$

that satisfies equations (3), (4), (5), (6), (7), (8), (21), (24), (26), (28), (30). In what follows, we study a dynamic equilibrium in the neighborhood of a non-stochastic steady state of the model.

## 3 Structure of Informed Capital

Let  $\nu_t \equiv A_t/N_t$  denote the ratio of bank capital to entrepreneurial capital, and call it the ratio of informed capital. We first seek a steady state value of  $\nu_t$ , (denoted by  $\nu$ , i.e.,  $\lim_{t \rightarrow \infty} \nu_t = \nu$ .)

**Proposition 1** *If  $\beta > \max\{\lambda^e, \lambda^b\}$ , there exists a steady state satisfying condition (23) where the ratio of informed capital ( $\nu$ ) is given by*

$$\nu = \frac{\gamma}{1 - \gamma} \left( \frac{\frac{\beta}{\lambda^e} - 1}{\frac{\beta}{\lambda^b} \left(1 + \frac{\Delta p}{p_H}\right) - 1} \right) > 0.$$

**Proof.** See Appendix A.3 ■

In other words, Proposition 1 implies that a steady state with a meaningful role for bank capital ( $\nu > 0$  and  $r_t^{a*} > 0$ ) exists if the entrepreneur's and banker's survival probabilities are lower than the household's rate of time preference. Intuitively the household must be sufficiently patient to let its bankers and entrepreneurs retain their earnings.

Next, we determine the value of  $\nu_t$  (denoted by  $\nu^{**}$ ) that would maximize leverage and investments in the economy, and by implication, the economy's output.

**Proposition 2** *The ratio of informed capital maximizing output ( $\nu^{**}$ ) is given by*

$$\nu^{**} = \frac{\gamma}{1 - \gamma}.$$

**Proof.** See Appendix A.4 ■

Proposition 2 shows that the output maximizing ratio of informed capital is equal to the elasticity of monitoring technology. To interpret this result, first recall that in equilibrium both bankers and entrepreneurs channel all their wealth into the investment projects, and the ratio  $\nu = A/N$  reflects their relative stakes. Now, suppose that banks have access to an efficient monitoring technology (the elasticity  $\gamma/(1 - \gamma)$  is large). Then an arrangement that maximizes aggregate investments involves intense monitoring. As the entrepreneurs' moral hazard problems are effectively alleviated, more funds for entrepreneurs' investments can be raised from depositors. But to ensure that bankers have incentives to monitor intensively requires a large (enough) banker stake (i.e., a high ratio  $\nu^{**} = A/N$ ).

In contrast, if the monitoring technology is not efficient (the elasticity  $\gamma/(1 - \gamma)$  is small), intensive monitoring is less useful. Then, in order to attract funding from depositors, it is better that entrepreneurs, rather than bankers, have large stakes and strong incentives to see that the projects succeed. Hence a low ratio  $\nu^{**} = A/N$  maximizes investment scale.

Comparison of Proposition 2 with Proposition 1 immediately yields our main analytical result:

**Proposition 3**  $\nu^{**} \begin{matrix} \geq \\ \leq \end{matrix} \nu$  if

$$\frac{\lambda^b}{\lambda^e} \begin{matrix} \leq \\ \geq \end{matrix} 1 + \frac{\Delta p}{p_H}.$$

In words, Proposition 3 suggests that the question of whether there is relative *scarcity* of bank or entrepreneurial capital in a steady state only depends on bankers' and entrepreneurs' exit rates and success probabilities of projects. The scarcity of bank capital prevails in a steady state for a larger range of parameter values than does the scarcity of entrepreneurial capital: Only if the bankers' survival probability is higher than the entrepreneurs'

survival probability by a factor strictly larger than one can the bankers accumulate more capital than that needed to maximize investments and output in the economy.

Proposition 3 has an important implication: Differentiating equation (24) around the steady state yields (see the Appendix for details)

$$\left. \frac{dN}{dA} \right|_{I^*} = - \frac{1 + \frac{\Delta p}{p_H} - \frac{\lambda^b}{\beta}}{\left(1 + \frac{\Delta p}{p_H}\right) \left(1 - \frac{\lambda^e}{\beta}\right)}. \quad (32)$$

If we view  $I_t^*(A_t, N_t)$  as given by equation (24) as the economy's production technology,  $dN/dA|_{I^*}$  defines the marginal rate of technical substitution of bank and entrepreneurial capital. Thus

$$\left. \frac{dN}{dA} \right|_{I^*} \begin{matrix} \leq \\ \geq \end{matrix} -1$$

if

$$\frac{\lambda^b}{\lambda^e} \begin{matrix} \leq \\ \geq \end{matrix} 1 + \frac{\Delta p}{p_H}.$$

In words, if bank capital is scarce, the (absolute) value of the marginal rate of technical substitution is greater than one and, as a result, increasing bank capital boosts aggregate investment more than does increasing entrepreneurial capital by an equal amount (and vice versa if entrepreneurial capital is scarce).

To better understand the mechanism that leads to underprovision of bank capital, we consider the case where  $\lambda^e = \lambda^b$ . Then, Proposition 3 unambiguously implies that there is too little bank capital in a steady state. Then, dividing equation (27) by equation (29) shows that in a steady state we have

$$\nu = \frac{R^b}{R^e}.$$

That is, because it is optimal for the household to let its entrepreneurs and bankers retain and reinvest all their earnings, bankers and entrepreneurs accumulate capital in relation to their conditional project returns in a steady

state.

Next note that maximizing leverage is practically equivalent to maximizing the (expected) pledgeable income,  $p_H q_t (R_t - R_t^b - R_t^e)$ , (i.e., the highest revenue share that can be pledged to depositors without jeopardizing entrepreneurs' and bankers' incentives), minus the cost of monitoring,  $m_t$ . But there is a trade-off: an increase in the bank monitoring will increase the entrepreneur's pledgeable income but reduce the banker's pledgeable income and consume bank capital that could otherwise have been loaned to entrepreneurs. Therefore the investment maximizing amount of bank involvement solves the following program:

$$\max_{m_t \geq 0} p_H q_t (R_t - R_t^b - R_t^e) - m_t$$

subject to equations (9), (10), (18), and  $r_t^{d*} = 0$ . The first-order condition for this problem may be written as

$$\frac{R_t^b + \frac{m_t}{p_H q_t}}{R_t^e} = \frac{\gamma}{1 - \gamma}.$$

Using  $\nu^{**} \equiv \gamma/(1 - \gamma)$ , a steady state version of this condition can be written as

$$\nu^{**} = \frac{R^b + \frac{m}{p_H q}}{R^e}$$

This suggests how the aggregate leverage is maximized when bankers' accumulation of capital also takes into account the real costs of monitoring in addition to their revenue share. In a steady state, however, the bankers' capital accumulation only reflects their revenue share. Therefore in a steady state bank capital is scarce.

## 4 Aggregate Uncertainty

Until now we have assumed that investment projects only involve idiosyncratic uncertainty. In this section we introduce an aggregate shock by as-

suming that in some period  $t$  project success probabilities are given by

$$\tilde{p}_{\tau t} = p_{\tau}(1 + \varepsilon_t), \quad \tau \in \{H, L\}, \quad (33)$$

where  $\varepsilon_t \in [\underline{\varepsilon}, 1/p_H - 1)$ , with  $\underline{\varepsilon} > -1$ , is an unanticipated change in the success probabilities of all projects. Such an investment shock may be due, e.g., to a disruptive technology or due to initial market perceptions (in which case the "shock" is a correction to the initial misperception).

We assume that the shock is realized after financing contracts have been signed, monitoring and project choices made, and price of capital goods determined. Furthermore, neither the pricing of capital goods nor financial contracts can be made contingent on realization of the shock. While in theory it would be possible to contract on the aggregate investment level, in practice such contracts are rare. In essence, we are assuming that capital goods are sold via forward contracts where the price of capital goods is agreed upon simultaneously with the (other) terms of the financing contract, before the delivery of capital goods occurs (see the appendix, for a detailed timing of events). This means that the price of capital goods in period  $t$ ,  $q_t$ , is unaffected by the shock in period  $t$ .<sup>9</sup>

To model the effects of an aggregate shock, we make the distinction between *bankers* and *banks* explicit. In our model, each bank employs a large number of bankers. Each banker monitors a single investment project. If the project succeeds, the entrepreneur retains his share of the project returns ( $R_t^e$ ). The rest of the returns ( $R - R_t^e$ ) are credited to the common account of the bank. If the project fails, neither the entrepreneur nor the bank gets anything. After the returns from all successful projects of the bank are collected, the bank compensates its bankers and refunds depositors according to the financing contract. A banker is paid only if the project that she monitored was successful. In other words, we assume that depositors' claims are senior within a bank; depositors are first paid from the bank's common funds, after which the successful bankers share what is left at the bank.

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<sup>9</sup>Some of these assumptions can be relaxed: in Appendix B we introduce a more complex model of the investment shock where we allow for spot trading of capital goods.

For brevity, we assume that the event of the worst shock,  $\underline{\varepsilon}$ , is large enough so that the bank never defaults on deposit contracts on the equilibrium path, i.e., in equilibrium deposits are always redeemed at par and the bank's sequential service constraint never binds. As a result, entrepreneurs and depositors always receive their promised share of project returns whereas bankers may get less (in case of a negative shock) or more (in case of a positive shock) than stipulated by the initial financing contract.<sup>10</sup>

Following an investment shock in period  $t$ , the aggregate entrepreneurial capital in period  $t + 1$  is given by

$$N_{t+1}(\varepsilon_t) = N_t [r_{t+1}^K + q_{t+1}(1 - \delta)] \lambda^e I_t (1 + r_t^e) p_H (1 + \varepsilon_t). \quad (34)$$

This directly follows from equations (29) and (33). Clearly the ratio of  $N_{t+1}(\varepsilon_t)$  to  $N_{t+1}$  in equation (34) is  $1 + \varepsilon_t$ . Even though each successful entrepreneur gets his share according to the financing contract, the aggregate entrepreneurial capital is reduced (increased) in the aftermath of a negative (positive) investment shock, because a smaller (larger) fraction of the entrepreneurs are successful.

In contrast, the aggregate bank capital in period  $t + 1$  following an investment shock in period  $t$  is given by

$$A_{t+1}(\varepsilon_t) = [r_{t+1}^K + q_{t+1}(1 - \delta)] \lambda^b I_t p_H [(R - R_t^e)(1 + \varepsilon_t) - R_t^w],$$

where the latter square brackets on the right-hand side contain the amount of project revenues received by each successful banker.

Using conditions (11) (recalling that  $r_t^{d*} = 0$ ), (12), (14), and (20), the evolution of aggregate bank capital can be re-written as

$$A_{t+1}(\varepsilon_t) = A_t \lambda^b \left( \frac{r_{t+1}^K + (1 - \delta) q_{t+1}}{q_t} \right) \left[ (1 + \varepsilon_t) (1 + r_t^a) + \varepsilon_t \frac{D_t}{A_t} \right]. \quad (35)$$

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<sup>10</sup>Nonetheless, we assume that depositors are not hedged against bank failure off the equilibrium path. In particular, if bankers employed by a bank do not monitor, the bank's borrowers choose to pursue bad projects. Then, we assume that the bank will not in expectation have enough funds to redeem its depositors at par (i.e.  $q_t p_L (R - R_t^e) < d_t / i_t$ ). Hence, depositors are only willing to put their money into a bank, if they know that the bankers have high enough own stakes, and proper incentives to monitor.



Dividing  $A_{t+1}(\varepsilon_t)$  of equation (35) by  $A_{t+1}$  of equation (28) yields  $1 + \varepsilon_t[1 + D_t/((1 + r_t^a) A_t)]$ . That is, compared with the effect of the shock on the aggregate entrepreneurial capital, its effect on aggregate bank capital is amplified by the factor  $D_t/((1 + r_t^a) A_t)$ . Besides the direct effect of the shock on bank capital via the project success probability, there is also an indirect amplifying effect via bankers' revenue share. For example, in the aftermath of a negative shock, not only do fewer bankers see their projects succeed but each successful banker get a smaller share of the revenues because of the seniority of depositors' claims. As a result the higher the bank leverage (defined as the debt-to-equity ratio,  $D_t/A_t$ ), the higher the multiplier of the shock.

It may be useful to look at the findings presented above from a slightly different angle. One key difference between banks and firms is that the former are larger and more diversified than the latter: each bank intermediates funding to a large number of firms. Perhaps somewhat paradoxically, the small size of individual firms protects entrepreneurs as a group against any levered impact of adverse shocks: if an investment project fails, the firm goes bankrupt and the entrepreneur loses his equity, but other entrepreneurs cannot be held responsible for the losses incurred by their failed peer(s). On the bank side things are different. Even when a (larger-than-expected) number of investment projects in a bank's portfolio fail, the bank does not declare partial bankruptcy: the bank still has to pay its debtors (depositors) and the adverse shocks are absorbed by bankers' equity. As a consequence, adverse aggregate shocks have a larger impact on bankers' equity than on entrepreneurial equity.

Although a shock has an asymmetric effect on the sharing of project revenues it does not affect the conditional project returns. Therefore the effect of the shock on the accumulation of physical capital is again directly related to its effect on project success probability. Equations (3) and (33) then imply that the aggregate physical capital in period  $t + 1$  following an investment shock in period  $t$  is given by

$$K_{t+1}(\varepsilon_t) = (1 - \delta) K_t + p_H R I_t (1 + \varepsilon_t).$$

## 5 Impulse Responses

We follow the Real Business Cycle literature in calibrating the parameters of the real economy.<sup>11</sup> Parameters related to the financial block are pinned down by the following data moments<sup>12</sup>: the excess return of bank capital, 14 % and its' capital-asset ratio, 8 %; the excess return on entrepreneurial capital (equity premium), 4.5 % and its' capital-asset ratio, 45 %, and the banks monitoring costs relative to bank assets, 1.5 %. The period is one year and the parameter values, summarized in Table 1, are adjusted accordingly.

Table 1: Calibrated parameter values

Parameter	Value	Note
<i>Parameters of the macro block</i>		
$\beta$	0.9804	discount factor
$\alpha$	0.33	capital share
$\delta$	0.0963	rate of decay of capital
$\xi$	2	parameter of the disutility of labor
$\phi$	0.5	$1/\phi$ Frish elasticity of labor supply
$\rho$	0.65	persistence of technology shock
$\sigma_\varepsilon$	0.006	std. dev. of the technology shock innovation
$\sigma$	2	$1/\sigma$ elasticity of intertemporal substitution
<i>Parameters of the financial block</i>		
$\lambda^e$	0.9382	survival rate of entrepreneurs
$\lambda^b$	0.8600	survival rate of bankers
$\gamma$	0.4158	$\gamma/(1 - \gamma)$ elasticity of monitoring function
$\Gamma$	0.0025	parameter of monitoring function
$p_H$	0.95	success probability of a good inv. project
$\frac{\Delta p}{p_H}$	0.1645	$\Delta p \equiv p_H - p_L = 0.1563$

Figure 1 shows the impulse responses of key real and financial sector variables to a negative investment shock.<sup>13</sup> As a benchmark, the similar impulse responses for a standard RBC model are given.<sup>14</sup> In the RBC model, invest-

<sup>11</sup>The details and motivation of the calibrated parameter values are given in Appendix A.6.

<sup>12</sup>See Appendix C.2 for the mapping of the moments and the parameters of the financial block.

<sup>13</sup>Impulse responses to a standard technology shock are given in Appendix A.7.

<sup>14</sup>The standard RBC model corresponds to our model except for financial intermediation and associated frictions.

ments increase to restore the lower-than-anticipated capital stock. Output and consumption decline due to the lower capital stock. In our model of banks, financial intermediation amplifies the impact of the investment shock on aggregate investment and output. The reason is twofold.

First, investment shocks have a strong effect on bank capital: Banks tend to be highly leveraged, with most of their funding consisting of deposits. Because of the seniority of depositors' claims, the banks must fully redeem the deposits, even if their investment projects are on average less successful than expected. As a result, in the aftermath of an adverse investment shock, bank capital serves as a shock buffer and absorbs most of the losses. In particular, bank capital is hit harder than aggregate entrepreneurial wealth, since the shock only affects those entrepreneurs whose projects fail, and limited liability caps the size of losses. Furthermore, when the level of bank capital and, by implication, the level of bank monitoring falls, entrepreneurs need to be given a larger share of future project returns to make them behave. This effect pushes entrepreneurial capital, and the return to that capital,  $r^e$ , upwards, not downwards.

Second, since bank capital is scarce relative to entrepreneurial wealth, a change in bank capital has a much larger effect on aggregate investment than does an equal (proportional) change in entrepreneurial wealth.

In sum, because an investment shock has a stronger effect on bank capital than on entrepreneurial wealth and because changes in bank capital matter more for the aggregate investment than changes in entrepreneurial wealth, financial intermediation amplifies the effects of a change in the expected project returns on aggregate investments. This strong effect on investment also translates into a sizeable effect on real output, employment and other macro variables.

## 6 Public funding of banks and firms

In this section, we analyze two possible government policy measures. First, the government can strengthen the balance sheets of banks, by injecting new government-owned equity. Second, the government can directly fund

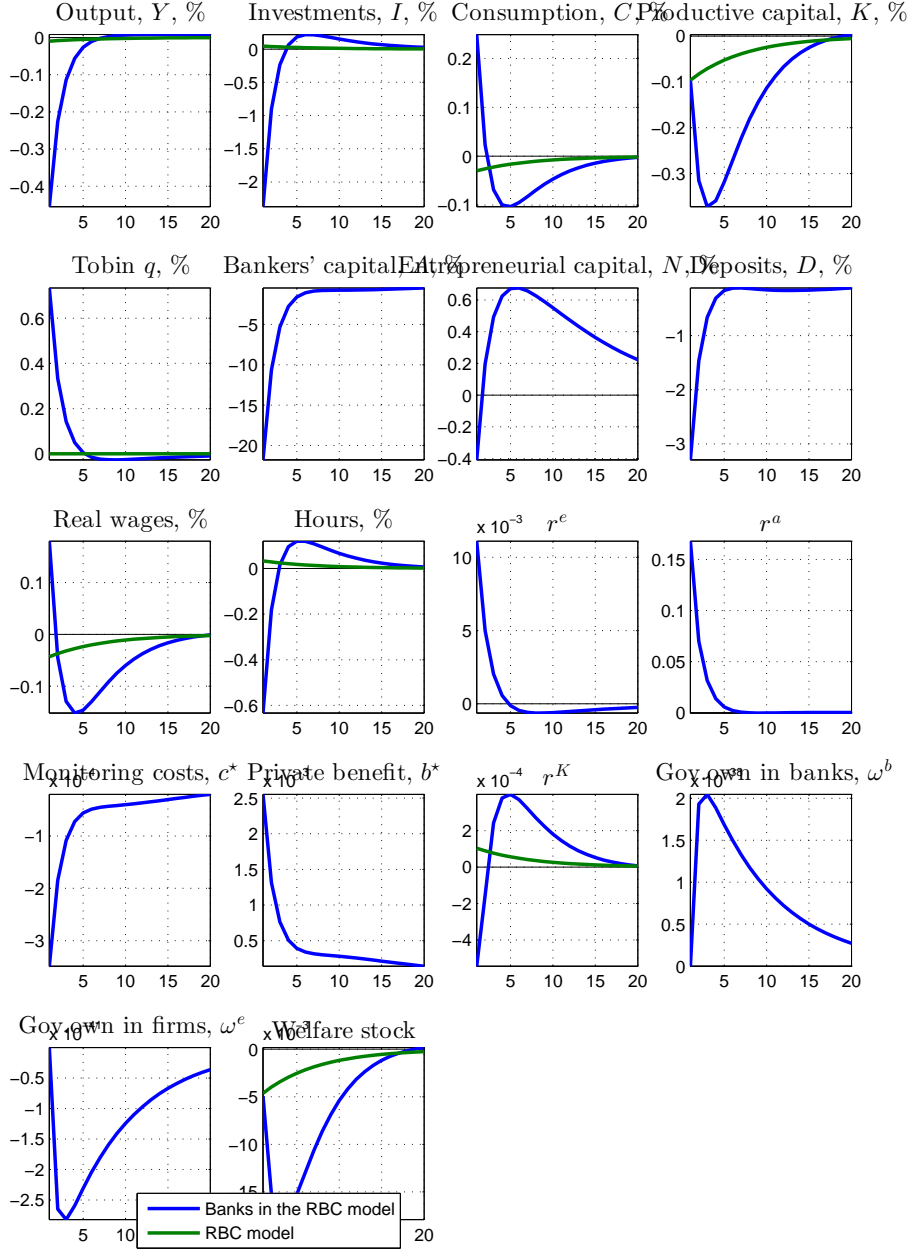


Figure 1: Impulse responses to a negative investment shock (1 percentage point decrease in success probabilities)

the non-financial firms. From the social point of view, both policies entail benefits and costs. The benefits arise since public funding of banks and/or firms renders the financial system, and the macro economy, less vulnerable to negative investment shocks. The social costs arise since public funding distorts bankers' and entrepreneurs' incentives: in "normal times", i.e. in the absence of an (adverse) investment shock, these policy measures actually curb bank lending and reduce investment.

Let us assume that the government injects an aggregate amount  $A_t^g \geq 0$  of equity capital into the banking system and funds entrepreneurial firms by an aggregate amount  $N_t^g \geq 0$ . As we shall discuss at the end of Section 6.2, public funding for non-financial firms can be thought of as either equity injections or loans. The government finances its funding program(s) with lump-sum taxes.

The government demands an expected rate of return of  $(1 + r_t^g)$  for its investments.<sup>15</sup> One way to interpret the conditions of public funding is that the government buys bank equity at (unit) price  $Q_t^b = (1 + r_t^a)/(1 + r_t^g)$  and firm equity at (unit) price  $Q_t^e = (1 + r_t^e)/(1 + r_t^g)$ . We assume that  $r_t^g > r_t^d$ : the government earns a positive premium over the deposit rate or the rate of return to funding from outside investors. If this were not the case, there would clearly be moral hazard, since banks and firms would want to be funded by the government. Finally, participation in these government programs is mandatory for all banks and/or firms, with an individual bank receiving  $a_t^g = a_t (A_t^g/A_t)$  of government-owned capital, and an individual firm getting  $n_t^g = n_t (N_t^g/N_t)$  of public funds.

We begin the analysis by looking at the costs of public policies in Subsection 6.1, and then move to the benefits in Subsection 6.2. Finally, we combine the cost side and the benefit side and conduct a cost-benefit analysis in Subsection 6.3, comparing bank capitalization with direct public funding of non-financial firms.

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<sup>15</sup>In the appendix we also allow for a more general case where the government may demand a different rate of return on its investments in banks and non-financial firms.

## 6.1 Social costs of public funding: incentives

We show in Appendix B.1 that public funding of banks and/or non-financial firms results in an aggregate investment level that is implicitly given by the equation

$$\begin{aligned} \left( \frac{A_t - \left( \frac{r_t^g - r_t^d}{1 + r_t^d} \right) A_t^g}{I_t^*} + \gamma \rho_t \right)^\gamma \left( \frac{N_t - \left( \frac{r_t^g - r_t^d}{1 + r_t^d} \right) N_t^g}{I_t^*} + (1 - \gamma) \rho_t \right)^{1-\gamma} \\ = \left( \frac{p_H}{\Delta p} \frac{\Gamma}{(1 + r_t^d)} \right)^{1-\gamma} \left( 1 + \frac{p_H}{\Delta p} \right)^\gamma \end{aligned} \quad (36)$$

Comparing equation (24) with equation (36) reveals that public funding *lowers* the aggregate investment level if  $r_t^g > r_t^d$ .

This harmful effect of public funding on aggregate investment arises because, when  $r_t^g > r_t^d$ , government-owned capital is just a more expensive source of funds for banks and firms than deposits from households. As a result the government ownership dilutes the bankers' and entrepreneurs' stakes in the projects, and the bankers' incentives to monitor and the entrepreneurs' incentive to invest are diminished. The weakening of the bankers' monitoring incentive makes bank participation costlier for entrepreneurs, further reducing entrepreneurs' investment incentive. As a result, the aggregate investment falls.

Public funding in a certain period  $t$  also affects the economy in future periods. Due to lower investments today, there will be less physical capital in the future. Furthermore, public funding lowers the rate of return to banker-owned capital and entrepreneurial capital in period  $t$

$$1 + r_t^a = \frac{1 + \gamma \rho_t \frac{I_t}{A_t} - r_t^{ga} \frac{A_t^g}{A_t}}{1 + \frac{\Delta p}{p_H}} \quad (37)$$

$$1 + r_t^e = 1 + (1 - \gamma) \rho_t \frac{I_t}{N_t} - r_t^{ge} \frac{N_t^g}{N_t} \quad (38)$$

and there will be less insider wealth in the subsequent period(s).

## 6.2 Social benefits of public funding: stability

Next we study the benefits of public policies. Public funding of banks and/or non-financial firms dampens the effects of aggregate investment shocks on the financial system and macroeconomy. In Appendix B.2 we show that if banks are provided with additional government-owned capital before an investment shock arrives, the dynamics of non-government owned bank capital in the aftermath of such a shock are described by the equation

$$A_{t+1}(\varepsilon_t) = A_t \lambda^b \left( \frac{r_{t+1}^K + (1 - \delta) q_{t+1}}{q_t} \right) \left[ (1 + \varepsilon_t)(1 + r_t^a) + \varepsilon_t \frac{D_t(A_t^g, N_t^g)}{A_t + A_t^g/Q_t^b} \right]. \quad (39)$$

Comparing equations (35) and (39) shows how public funds in banks and/or non-financial firms lower the bank leverage accelerator of shocks from  $D_t/A_t$  to

$$BL(A_t^g, N_t^g) = \frac{D_t(A_t^g, N_t^g)}{A_t + A_t^g/Q_t^b}, \quad (40)$$

where aggregate household deposits are given by<sup>16</sup>

$$D_t(A_t^g, N_t^g) = (1 + m_t(A_t^g, N_t^g)) I_t(A_t^g, N_t^g) - (N_t + A_t + A_t^g + N_t^g),$$

instead of  $D_t = D_t(0, 0)$ , as given by equation (25).

Equation (40) suggests that bank leverage is lowered both because the total bank equity is enhanced, thanks to equity  $A_t^g/Q_t^b$  purchased by the government (denominator of (40)) and because government capital  $A_t^g$  crowds out debt funding from households (numerator of (40)). On the other hand, direct public funding of non-financial firms  $N_t^g$  lowers bank leverage because it crowds out debt funding from households, intermediated by the banking system (numerator of (40)), but direct funding to non-financial firms does *not* strengthen the equity buffer of the banking system.

We have emphasized above how government funding reduces bank leverage and, therefore, lowers the accelerator of shocks. On the firm side, there

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<sup>16</sup>See the appendix for the derivation.

is no shock accelerator to be lowered: the government funding does not alter the dynamics of entrepreneurial capital given by (34). The only difference is that the determination of  $(1 + r_t^e)$  is now given by (38). In the case of bankruptcy, the limited liability of individual firms protects other firms from negative spillovers. It also protects the government funds: government funds invested in a successful firm A cannot be used to cover losses incurred by an unsuccessful firm B.

Finally notice that we cannot genuinely distinguish between public equity and debt funding of non-financial firms: if the investment project succeeds, both debt and equity holders (including the government) get their due share of the proceeds; if the project fails the firm goes bankrupt and nobody gets anything. Hence both interpretations (debt and equity) of public funding to non-financial firms are possible.

### 6.3 Funding banks or firms: cost-benefit analysis

Now we come to the main policy question of the paper. The government has decided to provide funding to the private sector. How should the resources be allocated between banks ( $A^g$ ) and firms ( $N^g$ ), if the aggregate size of the funding program is  $F$  ( $= A^g + N^g$ )?

To get precise analytical results, we make some further assumptions. First, we assume that the excess return that the government demands from banks and firms,  $dr_t \equiv r_t^g - r_t^d$ , is very small. This assumption can be motivated by the fact that larger premia would further distort incentives — see Section 6.2. Since the size of the investment shock,  $\varepsilon_t$ , is also assumed to be small, we can analyze separately the shock buffer effects and the incentive effects of public policies; to a first-order approximation we can ignore all cross effects, which are proportional to  $dr_t \times \varepsilon_t$  and hence very small.

We also assume that the government compensates, in a lump-sum manner<sup>17</sup>, bankers, entrepreneurs as well as the workers (depositors), for any *direct* costs due to capital injections. To be more specific, at the begin-

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<sup>17</sup>The compensation received by an individual banker or entrepreneur does not depend on his or her actions.



ning of period  $t + 1$  the government pays  $S^e = N^g dr_t$  to entrepreneurs,  $S^a = \left(1 + \frac{\Delta p}{p_H}\right)^{-1} A^g dr_t$  to bankers and  $S^w = \frac{\Delta p}{p_H} \left(1 + \frac{\Delta p}{p_H}\right)^{-1} A^g dr_t$  to workers.<sup>18</sup> These payments can be motivated by the fact that the government aims to minimize the negative effects of its policies on future insider wealth and future investments — see equations (37) and (38) above — while striving to avoid moral hazard: larger (lump-sum) payments could again render public intervention attractive to bankers and entrepreneurs.

Given these assumptions, public policies affect the economy through two channels only: a) lower bank leverage attenuates the amplification of (negative) investment shocks; b) government money dilutes bankers' and/or entrepreneurs' stakes and thereby lowers aggregate investments. These two channels have the following important implication for our analysis: If we can pin down the relative impact of bank capitalization and firm capitalization on a) shock amplification, and b) on distorting investments, we can actually pin down the *relative impact* of these two policies on *all model variables*, in the present and all future periods. In particular, we obtain the relative impact of these policies on utility (in the present and future).

We can derive a utility-based benefit ratio, arising from the dampening of a negative investment shock, between bank and firm capitalization. Similarly, we can derive a utility-based cost ratio, arising from diluted incentives, between bank and firm capitalization. Finally, comparing these ratios allows us to evaluate the policy options in utility terms.

Let us begin by studying the relative *benefits* of capitalizing banks versus firms. If the government injects  $A^g$  into banks and  $N^g$  into firms, bank leverage becomes

$$BL(A^g, N^g) = \frac{(1 + m)I - (A + N + A^g + N^g)}{A + A^g/Q^b} = \frac{D - A^g - N^g}{A + A^g/Q^b}; \quad F \in [0, D]$$

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<sup>18</sup>In the appendix we show that banks' monitoring costs are lowered by  $\frac{\Delta p}{p_H} \left(1 + \frac{\Delta p}{p_H}\right)^{-1} A^g dr_t$  as a result of government involvement (since there is less intense monitoring); hence the direct cost of capital injections to bankers is given by  $A^g dr_t - \frac{\Delta p}{p_H} \left(1 + \frac{\Delta p}{p_H}\right)^{-1} A^g dr_t = \left(1 + \frac{\Delta p}{p_H}\right)^{-1} A^g dr_t$ . Also remember that in our framework banks pay the monitoring costs to workers; hence workers loose  $\frac{\Delta p}{p_H} \left(1 + \frac{\Delta p}{p_H}\right)^{-1} A^g dr_t$ .

where  $D = (1 + m)I - (A + N)$  is steady state deposits, in the absence of government policies. Remember that up to a first-order approximation we can here ignore the effect of public policies on  $m_t$  and  $I_t$ : these cross effects are proportional to  $dr_t \times \varepsilon_t$ . The benefits of capitalization derive from lower leverage: less levered banks are more resilient to a negative investment shock. Then the *benefit ratio* of injecting the marginal dollar into banks rather than firms is given by

$$\begin{aligned} BR(A^g, N^g) &= \frac{\partial BL(A^g, N^g) / \partial A^g}{\partial BL(A^g, N^g) / \partial N^g} = \frac{1 + (D - N^g) / (Q^b A)}{1 + A^g / (Q^b A)} \\ &= 1 + \frac{(D - F) / (Q^b A)}{1 + A^g / (Q^b A)}; \quad F \in [0, D] \end{aligned} \quad (41)$$

where the last form is derived using the equality  $F = A^g + N^g$ .

Since  $BR > 1$ , injecting capital into banks is a more effective way to reduce leverage than funding firms: a capital injection into banks strengthens the banks' shock cushion, whereas providing public funding to firms only crowds out deposits. The benefit calculus tends to favor bank capitalization in particular, when the scale of public funding,  $F$ , is relatively small. Initially any new capital put into banks has a large proportional effect on the amount of bank equity, and on banks' shock cushions. For example, taking our baseline calibration and assuming that the size of capitalization is small ( $F/A$  is close to zero, and as a consequence also  $A^g/A$  and  $N^g/A$  are close to zero), gives a benefit ratio  $BR \approx (1 + D / (Q^b A)) = 11.3$ . However, the benefit ratio becomes smaller as the size of capital injections increases. For example, taking our baseline calibration and assuming for simplicity that the government targets only banks ( $A^g = F$  and  $N^g = 0$ ), gives  $BR = 6.0$ , when  $F/A = 1$  and  $BR = 4.1$  when  $F/A = 2$ . Intuitively, when banks have more equity (banker-owned or government-owned) in their balance sheets, any additional unit of capital has a smaller proportional effect on the shock cushions.

Next we examine the social *costs* of public funding. From (36) we see that bank capitalization is akin to de facto *decreasing* banker-owned equity by a small amount,  $A^g dr_t$ , while firm capitalization is akin to *decreasing*

entrepreneurial capital by a small amount,  $N^g dr_t$ . Around the steady state, any policy-induced reduction in investment represents a distortion. Then, the *cost ratio* of allocating the marginal dollar of government money into banks, as opposed to non-financial firms, is given by

$$CR = \frac{\left(-\frac{dI_t}{dA_t} dr_t\right)}{\left(-\frac{dI_t}{dN_t} dr_t\right)} = \left| \frac{dN}{dA} \right| \Big|_{I^*} = \frac{1 - \frac{\lambda^b}{\beta} + \frac{\Delta p}{p_H}}{\left(1 + \frac{\Delta p}{p_H}\right) \left(1 - \frac{\lambda^e}{\beta}\right)},$$

where the steady state marginal rate of technical substitution  $dN/dA|_{I^*}$  was derived in Section 3.<sup>19</sup>

The distortions arise because government ownership in either banks or non-financial firms dilutes the bankers' or entrepreneurs' stakes and blunts their incentives to monitor and to invest. In equilibrium (near the steady state) bank capital is scarce compared to firm capital; see the analysis in Section 3. Then capital injections into banks dilute bankers' stakes proportionally more than capital injections into firms dilute entrepreneurs' stakes. This observation is also reflected in the relative costs of policy measures: with our baseline calibration we get  $CR = 5.7$ . Hence, capitalizing banks brings about nearly 6 times larger distortions than targeting non-financial firms.

So far we have compared the benefits of funding banks versus firms, summarized by  $BR$  and the costs stemming from the different policy measures, summarized by  $CR$ . However, when choosing whether to finance banks or firms, it is important to evaluate the tradeoff between costs and benefits. To study the tradeoff, we compute the ratio,  $BCR$ , of the benefit ratio,  $BR$ , to the cost ratio,  $CR$ :

$$BCR(A^g, N^g) = \frac{BR(A^g, N^g)}{CR} = \left( \frac{1 + (D - N^g) / (Q^b A)}{1 + A^g / (Q^b A)} \right) \left| \frac{dA}{dN} \right| \Big|_{I^*}. \quad (42)$$

Alternatively,  $BCR$  can be thought of as the ratio of the benefit-cost ratio of bank capitalization to the benefit-cost ratio of direct funding to firms.

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<sup>19</sup>Remember that the marginal rate of technical substitution is defined by the equation  $\frac{dI_t}{dA_t} dA_t + \frac{dI_t}{dN_t} dN_t = 0 \Leftrightarrow \frac{dN_t}{dA_t} = -\frac{dI_t}{dA_t} / \frac{dI_t}{dN_t}$ .

If  $BCR > 1$  the government gets a better tradeoff between costs and benefits in targeting banks rather than firms. In other words, no matter what relative weights the government, or the society, assigns to the benefits and costs of capital injections, the government should invest the marginal dollar into the banks. The relative weights the government assigns to the benefits and costs can depend, for example, on the (perceived) probability and (perceived) size of adverse investment shocks. If  $BCR < 1$ , we have the opposite situation, and the government should allocate the marginal dollar to the non-financial firms. Finally, if  $BCR = 1$ , both options are equally good, or equally bad, ways to invest the marginal euro or dollar.

Next we state the main policy result of the paper. See also Figure 2 for an illustration.

**Proposition 4** *Assume that  $1 < CR < BR^{\max}$ , where  $CR = \left| \frac{dN}{dA} \right|_{I^*}$  is the cost ratio and  $BR^{\max} = BR(0, 0) = 1 + D/(Q^b A)$  is the maximum value of the benefit ratio. Then the optimal structure of public funding can be characterized with the help of threshold values  $F_L = CR^{-1} (BR^{\max} - CR) Q^b A$  and  $F_U = (BR^{\max} - CR) Q^b A$ , where  $F_U > F_L > 0$ .*

*a) If the aggregate scale of public funding  $F \leq F_L$  the government should target only banks:*

$$A^g = F, \quad N^g = 0.$$

*b) If the aggregate scale of public funding  $F \in (F_L, F_U)$ , the government should target both banks and non-financial firms:*

$$A^g = \left( \frac{F_U - F}{F_U - F_L} \right) F_L, \quad N^g = \left( \frac{F - F_L}{F_U - F_L} \right) F_U. \quad (43)$$

*c) If the aggregate scale of public funding  $F \geq F_U$ , the government should target only non-financial firms:*

$$A^g = 0, \quad N^g = F.$$

**Proof.** See Appendix B.3. ■

Proposition 4 essentially describes a pecking order of public funding: As

stated in item a), the government should target only banks, if the size of the public funding is small or moderate. Non-financial firms should be targeted, along with banks, only if the size of public funding exceeds a certain limit,  $F_L$ . Typically, the critical value  $F_L$  of policy measures, given in Proposition 4, is relatively large. For example, with our baseline calibration,  $F_L/A = 1.1$ . In this case, Proposition 4 indicates that the government should target only banks, unless the size of capital injections exceeds banker-owned equity. To sum up the argument: with small and moderate sized capitalizations, the benefit calculus, favoring banks, clearly trumps the cost calculus, favoring firms.

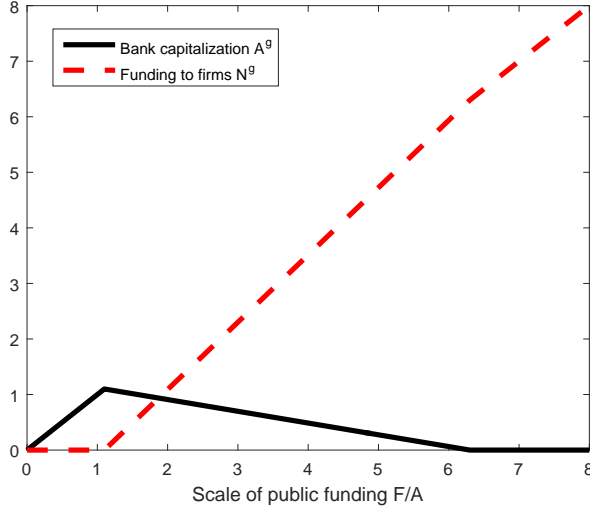


Figure 2: Optimal public funding of banks and firms

If the total amount of public funding is larger,  $F \in (F_L, F_U)$ , the government should target both banks and non-financial firms. Moreover, the sum of money allocated to non-financial firms ( $N^g$ ) should be increasing in  $F$ , by more than one-to-one, while the sum of money ( $A^g$ ) allocated to banks should be actually *decreasing* in  $F$ . This latter finding may seem somewhat surprising. To understand the intuition behind the result, recall that the relative benefits of targeting banks decreases as the size of capital injections increases: the impact of new capital on banks' shock cushion becomes proportionally smaller, if banks already have a significant amount of equity in their balance

sheets. Then the benefit calculus no longer overshadows the cost calculus and one should pay attention to both sides of the cost-benefit analysis. Second, notice that, with the size of bank capitalization  $A^g$  taken as given, allocating government-owned equity to non-financial firms actually dents the benefit advantage of targeting banks: more government-owned equity in non-financial firms implies lower bank leverage — due to the crowding-out of deposits — and lower leverage in turn implies that a larger shock cushion is of less value (using the first form of expression (41), we get  $\partial BR/\partial N^g < 0$  when  $A^g$  is fixed). These two observations then explain the result stated in item b): When a certain limit  $F_L$  is reached, the larger distortions involved in bank capitalization imply that the extra money should be put into non-financial firms rather than banks. Since funding non-financial firms (further) lowers the benefit advantage of bank capitalization, this further tilts the scales in favor of allocating the money to firms.

The arguments presented above also help to explain why the government should only target non-financial firms when the size of capital injections exceeds the second threshold,  $F \geq F_U$ . Essentially, with very large-scale public funding, the cost calculus (favoring direct funding to firms) trumps the benefit calculus (favoring bank capitalization). However, the result stated in item c) of the Proposition is perhaps not very relevant for practical purposes, since the threshold value  $F_U$  is typically very high. For example, with our baseline calibration  $F_U/A = 6.3$ . Hence, the amount of public funding should be more than 6 times banker-owned capital for public funding to firms only to be the optimal strategy.

Finally, the proposition hinges on the conditions  $CR > 1$  and  $CR < BR^{\max}$ . As explained in Section 3, the condition  $CR = |dN/dA|_{I^*} > 1$  is likely to hold in our model: essentially, in the steady state bank capital is typically scarce compared to firm capital. However, if instead  $CR = |dN/dA|_{I^*} \leq 1$  — essentially meaning that firm capital is scarce — bank capitalization ( $A^g = F$ ,  $N^g = 0$ ) would be the optimal policy for any scale of public funding  $F \in [0, D]$ . Recall that the benefit calculus favors bank capitalization since  $BR > 1$ , and here the cost calculus would also favor targeting banks, as  $CR \leq 1$ . In Appendix B.4 we explain why the condition

$CR < BR^{\max}$  is also likely to hold in our model, with any plausible calibration. If, however,  $CR > BR^{\max}$ , public funding would distort bankers' incentives so much more than entrepreneurs' incentives that public funding of firms only ( $A^g = 0$ ,  $N^g = F$ ) would be the optimal strategy for any value of  $F$ .

## 7 Concluding Remarks

In this paper we developed a macro-finance model, where both banks' and firms' balance sheets matter. We showed that in equilibrium, bank capital tends to be scarce, compared to firm capital. Then, a given change in bank capital has a larger impact on aggregate investment than a corresponding change in firm capital. Also, due to bank leverage, bank capital is vulnerable to (negative) investment shocks. For these reasons, bank capital may play a more crucial role in macro-financial linkages and macro dynamic, than does firm capital.

We used our model to study the capitalization of banks and non-financial firms in times of crisis. Our main result establishes a pecking order of public funding: banks should be capitalized first, but if the government's resources are ample enough, the additional dollar should be placed in non-financial firms.

The result arises from the following benefit-cost analysis: Given the scarcity of bank capital, capitalizing the banking system stabilizes the economy more effectively than direct public funding of non-financial firms. Hence bank capitalization generates larger social benefits. However — also due to the scarcity of bank capital — public funding distorts incentives more when placed in banks than when placed in non-financial firms. In other words, bank capitalization also entails larger social costs. Finally, the relative social benefits of bank capitalization diminish as the amount of public funding increases. Initially, capital injections have a (very) large proportional effect on banks' shock cushions, but this effect diminishes as banks' balance-sheet equity — banker-owned or government-owned — increases.

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## A Appendix

### A.1 Investment size at project level

In this appendix we derive equations (15) and (16). From the entrepreneur's and banker's incentive constraints, (9) and (10), we see that the entrepreneur and the banker must get no less than  $R_t^e = \frac{b(m_t)}{q_t \Delta p}$  and  $R_t^b = \frac{(1+r_t^d)m_t}{q_t \Delta p}$  respectively, in case of success, as otherwise they will misbehave. Then the return-sharing constraint (14) shows that depositors can be promised at most

$$R_t^w = R - \frac{(1+r_t^d)m_t + b(m_t)}{q_t \Delta p}. \quad (44)$$

Substituting equation (44) for the depositor's participation constraint (11) yields

$$p_H \left\{ q_t R - \frac{[(1+r_t^d)m_t + b(m_t)]}{\Delta p} \right\} = (1+r_t^d) \frac{d_t}{i_t}. \quad (45)$$

Next, we combine the banker's incentive constraint (10) with his participation constraint (12) and the input resource constraint (13) to obtain

$$\frac{d_t}{i_t} = 1 + m_t - \frac{p_H}{\Delta p} \left( \frac{1+r_t^d}{1+r_t^a} \right) m_t - \frac{n_t}{i_t},$$

which can be then substituted for equation (45). Solving the resulting equation for  $i_t$  gives equation (15) and expression (16).

### A.2 Timing of Events

Within each period  $t$  there are three main stages. In the first stage the household members separate into their occupations, the heads of households make their consumption-savings decisions, and final goods are produced using capital and labor.

The production of capital goods takes place in the second stage, which is divided into five sub-stages: First, financing contracts among entrepreneurs, bankers and depositors (workers) are signed. These contracts determine

whether and how the project is financed, its size, and how eventual revenues are divided. Depositors place their funds in banks, who extend funding to entrepreneurs according to the financing contract. Second, bankers choose their intensity of monitoring. Third, entrepreneurs choose their projects. Fourth, successful projects yield new units of capital goods that are sold. Finally, the proceeds are divided among depositors, bankers and entrepreneurs according to the terms of the financial contract.

In the third main stage, survival probabilities of bankers and entrepreneurs are realized. Exiting bankers and entrepreneurs give their accumulated assets to households.

Note that entrepreneurs are assumed to sell the capital goods that they produce. Yet our equations in Section 2.2 show that final good firms rent — instead of owning — the capital stock that they need in production. This is consistent with the existence of perfectly competitive capital rental firms, fully owned by households. These capital rental firms purchase capital goods from successful entrepreneurs, rent capital services to final goods firms, and refund the rental income to their owners.

Note also that bankers can commit to monitoring before entrepreneurs make their project choice, as in Holmstrom and Tirole (1997). This sequential timing rules out mixed strategy equilibria. But in some other cases the results are not sensitive to the timing of events specified above. For example we could assume that capital goods from successful projects are first divided among the contracting parties who will subsequently sell them to capital rental firms.

### A.3 Proof of Proposition 1

**Proof.** Substitution of the incentive constraints (9) and (10), together with equation (18) and  $r^{d*} = 0$  for equations (27) and (29) gives

$$A_{t+1} = \frac{[r_{t+1}^K + q_{t+1}(1 - \delta)]}{q_t \Delta p} p_H \lambda^b m_t I_t$$

and

$$N_{t+1} = \frac{[r_{t+1}^K + q_{t+1}(1 - \delta)]}{q_t \Delta p} p_H \lambda^e \Gamma m_t^{-\frac{\gamma}{1-\gamma}} I_t.$$

Thus, in a steady state we must have

$$A = \left( \frac{r^K}{q} + 1 - \delta \right) \frac{p_H}{\Delta p} \lambda^b c I \quad (46)$$

and

$$N = \left( \frac{r^K}{q} + 1 - \delta \right) \frac{p_H}{\Delta p} \lambda^e \Gamma m^{-\frac{\gamma}{1-\gamma}} I. \quad (47)$$

Here and in what follows we denote a steady state of some time-depenent variable  $X_t$  by  $X$ , i.e.,  $\lim_{t \rightarrow \infty} X_t = X$ . Dividing equation (46) by equation (47) implies that

$$\nu \equiv \frac{A}{N} = \frac{\lambda^b m^{\frac{1}{1-\gamma}}}{\lambda^e \Gamma}. \quad (48)$$

Next, substitution of equation (22) for equation (19) yields, after some algebra, the steady state value of  $m$  as

$$m = \frac{\gamma \rho + \frac{A}{I}}{1 + \frac{p_H}{\Delta p}}. \quad (49)$$

Equation (24) can be rewritten at a steady state as

$$\frac{\gamma \rho + \frac{A}{I}}{1 + \frac{p_H}{\Delta p}} = \left[ \frac{\frac{p_H}{\Delta p} \Gamma}{(1 - \gamma) \rho + \frac{N}{I}} \right]^{\frac{1-\gamma}{\gamma}}. \quad (50)$$

Combining equations (49) and (50) and solving for  $\rho$  yields

$$\rho = \frac{1}{1 - \gamma} \left( \frac{p_H}{\Delta p} \Gamma m^{-\frac{\gamma}{1-\gamma}} - \frac{N}{I} \right). \quad (51)$$

Inserting equation (51) into (49) gives

$$m \left( 1 + \frac{p_H}{\Delta p} \right) = \frac{\gamma p_H \Gamma}{(1 - \gamma) \Delta p} m^{-\frac{\gamma}{1-\gamma}} + \frac{A}{I} - \frac{\gamma N}{(1 - \gamma) I}.$$

After substituting equations (46) and (47) for the above formula we obtain

$$1 + \frac{\Delta p}{p_H} = \Gamma m^{-\frac{1}{1-\gamma}} \left[ \frac{\gamma}{1 - \gamma} + \lambda^e \left( \frac{r^K}{q} + 1 - \delta \right) \left( \frac{\lambda^b m^{1+\frac{\gamma}{1-\gamma}}}{\lambda^e \Gamma} - \frac{\gamma}{1 - \gamma} \right) \right].$$

By using the definition of  $\nu$  from equation (48), this can be rewritten as

$$\nu \frac{\lambda^e}{\lambda^b} \left(1 + \frac{\Delta p}{p_H}\right) = \frac{\gamma}{1 - \gamma} + \lambda^e \left(\frac{r^K}{q} + 1 - \delta\right) \left(\nu - \frac{\gamma}{1 - \gamma}\right).$$

Solving for  $\nu$  from the above equation gives

$$\nu = \left(\frac{\gamma}{1 - \gamma}\right) \left[ \frac{\frac{1}{\lambda^e} - \frac{r^K}{q} - 1 + \delta}{\frac{1}{\lambda^b} \left(1 + \frac{\Delta p}{p_H}\right) - \frac{r^K}{q} - 1 + \delta} \right]. \quad (52)$$

Finally, from the household's Euler equation (5), we see that in steady state we must have

$$\beta = \frac{q}{r^K + (1 - \delta)q}. \quad (53)$$

Using equation (53), equation (52) can be rewritten as

$$\nu = \left(\frac{\gamma}{1 - \gamma}\right) \left[ \frac{\frac{\beta}{\lambda^e} - 1}{\frac{\beta}{\lambda^b} \left(1 + \frac{\Delta p}{p_H}\right) - 1} \right].$$

It is evident that  $\nu > 0$  if the condition

$$\beta > \max \{\lambda^e, \lambda^b\}. \quad (54)$$

holds. Clearly, if  $\lambda^b > \lambda^e$ , condition (54) is a sufficient condition. Furthermore if condition (54) holds, equation (28) implies that in a steady state we must have  $r^{a*} > 0$ , i.e., condition (23) is satisfied. ■

## A.4 Proof of Proposition 2

**Proof.** Let  $G_t = (A_t + N_t)/I_t$ . We seek the value of  $\nu_t$  that maximizes the aggregate leverage  $1/G_t = I_t/(A_t + N_t)$  and by implication, aggregate investment and output for a given level of aggregate informed capital  $A_t + N_t$ . Using  $A_t/I_t = \nu_t G_t/(1 + \nu_t)$  and  $N_t/I_t = G_t/(1 + \nu_t)$  (and recalling that  $r_t^{d*} = 0$ ) we can rewrite equation (24) — which determines the equilibrium

aggregate investment level  $I_t^*$  — as

$$\left( \frac{\nu_t G_t^*}{1 + \nu_t} + \gamma \rho_t \right)^\gamma \left[ \frac{G_t^*}{1 + \nu_t} + (1 - \gamma) \rho_t \right]^{1-\gamma} = \left( \frac{\Gamma p_H}{\Delta p} \right)^{1-\gamma} \left( 1 + \frac{p_H}{\Delta p} \right).$$

Differentiating this equation with respect to  $G_t^*$  and  $\nu_t$  gives

$$\frac{dG_t^*}{d\nu_t} \Big|_{I_t^*} = \frac{G_t^* \left\{ 1 - \gamma - \left( \frac{\nu_t G_t^*}{1 + \nu_t} + \gamma \rho_t \right)^{-1} \left[ \frac{G_t^*}{1 + \nu_t} + (1 - \gamma) \rho_t \right] \gamma \right\}}{(1 + \nu_t) \left\{ \left( \frac{\nu_t G_t^*}{1 + \nu_t} + \gamma \rho_t \right)^{-1} \left[ \frac{G_t^*}{1 + \nu_t} + (1 - \gamma) \rho_t \right] \gamma \nu_t + 1 - \gamma \right\}}. \quad (55)$$

The aggregate leverage is maximized when  $G_t^*$  is minimized. A potential minimum is obtained if the term in the curly brackets in the numerator on the right-hand side of equation (55) is zero, i.e., if

$$\frac{\frac{\nu_t}{1 + \nu_t} G_t^* + \gamma \rho_t}{\frac{G_t^*}{1 + \nu_t} + (1 - \gamma) \rho_t} = \frac{\gamma}{1 - \gamma}.$$

This simplifies to

$$\nu_t = \frac{\gamma}{1 - \gamma} \equiv \nu^{**}.$$

It is easy to see from equation (55) that  $dG_t^*/d\nu_t|_{I_t^*} < 0$  for  $\nu_t < \nu^{**}$  and  $dG_t^*/d\nu_t|_{I_t^*} > 0$  for  $\nu_t > \nu^{**}$ . Therefore,  $\nu^{**}$  indeed characterizes the value of  $\nu_t$  that minimizes  $G_t^*$  and thereby maximizes the aggregate leverage and output. ■

## A.5 Calculation of Marginal Rate of Technical Substitution

Differentiating (24) with respect to  $A_t$  and  $N_t$  gives

$$\frac{dN_t}{dA_t} \Big|_{I_t^*} = -\frac{\gamma}{(1 - \gamma)} \left[ \frac{\frac{N_t}{I_t^*} + (1 - \gamma) \rho_t}{\frac{A_t}{I_t^*} + \gamma \rho_t} \right].$$

Evaluating this at a steady state and using equations (51) and (49) in the numerator and the denominator of the term in the square brackets, respectively,



yields, after some algebra,

$$\left. \frac{dN}{dA} \right|_{I^*} = - \frac{\gamma \Gamma m^{-\frac{1}{1-\gamma}}}{(1-\gamma) \left(1 + \frac{\Delta p}{p_H}\right)}.$$

Using equation (48) to substitute  $\lambda^b / (\lambda^e \nu)$  for  $\Gamma m^{-\frac{1}{1-\gamma}}$  and Proposition 1 to eliminate  $[\gamma / (1-\gamma) \nu]$  we get

$$\left. \frac{dN}{dA} \right|_{I^*} = - \frac{\lambda^b}{\left(1 + \frac{\Delta p}{p_H}\right) \lambda^e} \left[ \frac{\frac{\beta}{\lambda^b} \left(1 + \frac{\Delta p}{p_H}\right) - 1}{\frac{\beta}{\lambda^e} - 1} \right].$$

This simplifies to

$$\left. \frac{dN}{dA} \right|_{I^*} = - \frac{1 + \frac{\Delta p}{p_H} - \frac{\lambda^b}{\beta}}{\left(1 + \frac{\Delta p}{p_H}\right) \left(1 - \frac{\lambda^e}{\beta}\right)}.$$

## A.6 Calibration

In calibrating the real sector of the model, we can follow the Real Business Cycle literature. A period is one year. The household utility function parameters are calibrated to imply relatively modest risk aversion and fairly inelastic labour supply:  $\sigma = 2$ ,  $\phi = 0.5$ , and  $\xi = 2$ . The discount factor  $\beta$  is calibrated to 0.98, which approximately corresponds to an annual real interest rate of 2%. The depreciation rate  $\delta$  is set at 0.0963, which is a typical value in the business cycle literature, and results in an investment-to-capital ratio of 0.07. To keep the model as close as possible to the basic ‘text-book’ framework, we adopt the normalization  $p_H R = 1$ . This leads to the standard law of motion of the physical capital stock,  $K_{t+1} = (1 - \delta) K_t + I_t$  (see equation (3)).

The output elasticity of capital in the final goods sector (see equation (6),  $\alpha$ , is set at the often-used value of  $1/3$ . In the numerical analysis we introduce a shock to the labor augmenting technology  $Z_t$  in equation (6). The shock follows an autoregressive process with persistence  $\rho_Z = 0.65$  and standard deviation  $\sigma_Z = 0.006$ .

In constructing a steady-state we introduce an investment subsidy to redress the moral hazard in investments. This modification results in an efficient steady-state corresponding to that of the standard RBC model. The output shares of the investments and consumption are roughly 20% and 80%, respectively.

Calibration of the parameters of the financial block, while being less standardized, only requires that we find values for excess returns to banks' and entrepreneurial firms' capital, their capital ratios, and bankers' monitoring costs (see Appendix C.2 for details). The rest of the required parameter values can be calculated from these empirical characteristics. The resulting parameter values are reported in the lower panel of Table 1. Note that Proposition 3 implies scarcity of bank capital in a steady state under these parameter values.

The steady-state (excess) rate of return on bank capital,  $r^a$ , is calibrated based on estimates of Albertazzi and Gambacorta (2009) who find the average after-tax return on bank equity in 1999–2003 to vary from 15% in the UK and 14% in the USA to 7% in the euro area. In line with these figures, Haldane and Alessandri (2009) find the pre-tax return on bank equity in the UK to be around 20% on average over the recent decades. We set  $r^a$  at 0.14 which lies in the mid-range of these estimates.

To parametrize the steady-state (excess) rate of return on entrepreneurial capital,  $r^e$ , we first take the value of 6.5% as the average return to capital in the economy, commonly used in the real business cycle literature, and then subtract a riskless rate of 2% from it, yielding  $r^e = 0.045$ .

As to the value for the entrepreneurial firms' steady-state capital ratio,  $N/I$ , the literature suggests substantial intertemporal and cross-section variation (e.g., Rajan and Zingales, 1995, de Jong, Kabir and Ngyen, 2008, Graham and Leary, 2011, and Graham, Leary, and Roberts, 2014). We choose the value of 0.45, which is close to the post-1990 estimate for the US by Graham *et al.* (2014).

We calculate the banks' capital ratio by subtracting monitoring costs from banks' assets since that gives us the amount of funds that the banks allocate to investment projects. As a result the bank's steady-state capital

ratio of our interest is given by  $A/(A + D - mI) = A/(I - N)$ . Since in our model the banks have a stake in the projects they fund, the closest empirical counterpart for our bank capital is Tier 1 capital, which includes banks' common stocks and retained earnings. Typical estimates, see, e.g., Acharya and Steffen (2014), of Tier 1 capital to — non-risk adjusted — assets vary between 4 percent and 8 percent. Our model focuses on firm loans, abstracting from other bank assets. We set  $A/(I - N) = 0.08$  to account for the riskiness of firm loans.

Finding a reasonable estimate for monitoring costs is not easy. Based on the estimations of Albertazzi and Gambacorta (2009) and Philippon (2013), the unit cost of financial intermediation could be 1% – 4% of a bank's total assets. But as their unit cost measures include activities in addition to monitoring, that estimate only provides an upper bound for the ratio of monitoring costs to assets. However, firm loans arguably involve more intense monitoring than many other asset classes in a bank's balance sheet. Based on these observations, we choose a monitoring cost to asset ratio ( $mI/(I - N)$ ) of 1.5%.

## A.7 Impulse responses to a technology shock

Figure 3 portrays the impulse responses of key real and financial sector variables to a positive technology shock. As a benchmark, we also show the real sector impulse responses in a standard RBC model which corresponds to our model except for financial intermediation and associated frictions.

Impulse responses in Figure 3 indicate that the first-round effects of the technology shock on investments and working hours are dampened because the financial intermediation and frictions introduced in this paper imply sluggish accumulation of bank and entrepreneurial capital. As a result the increased output generated by the positive technology shock is allocated to consumption and wages to a larger extent than in a basic RBC framework. Note that our model does not include habit formation and investment adjustment costs, which would smooth out the consumption and investment effects of the technology shock.

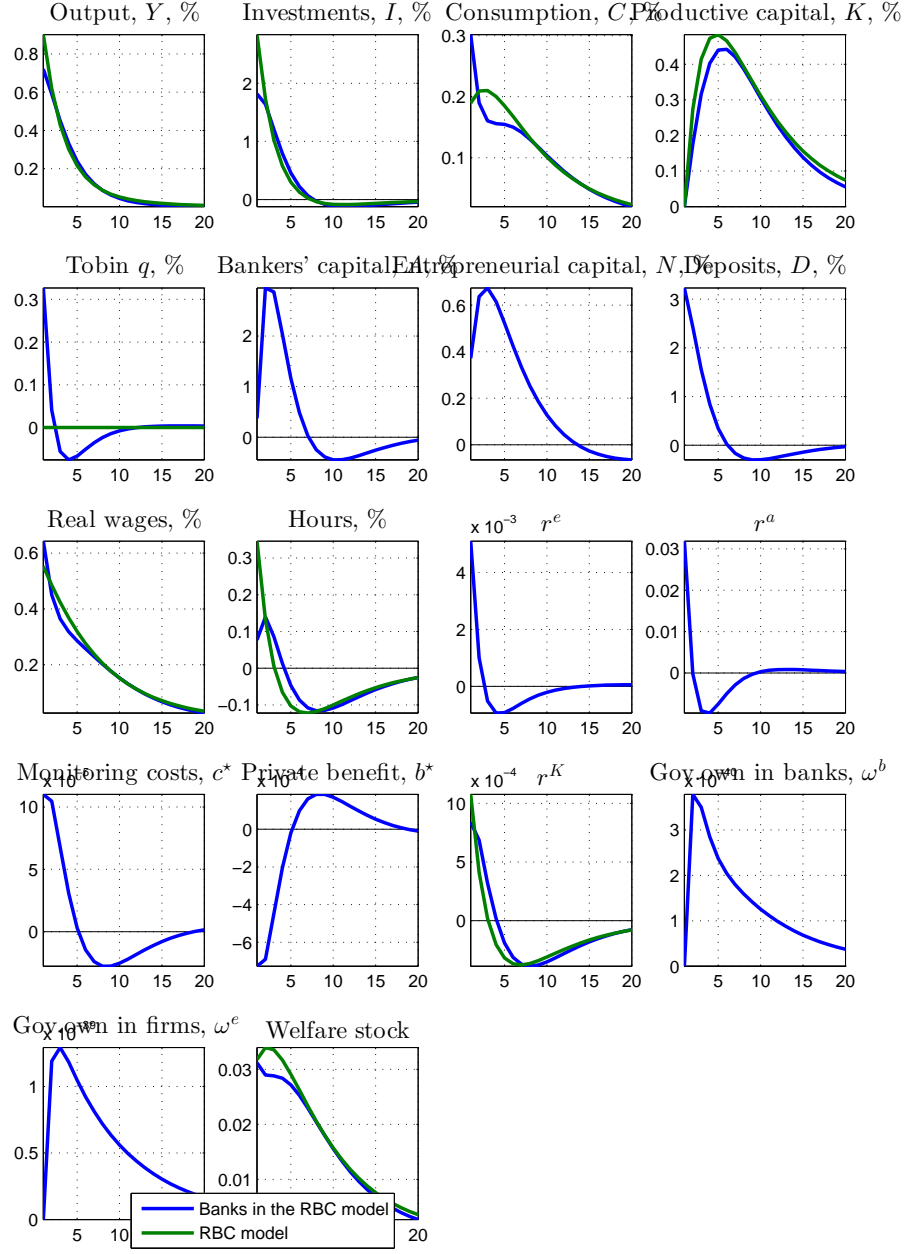


Figure 3: Impulse responses to a positive technology shock (1 % increase in  $Z_t$ )

## B Public funding

### B.1 Implications for the financing contract

We assume that the government injects an aggregate amount  $A_t^g$  of capital into the banking system and an aggregate amount  $N_t^g$  of capital into non-financial corporations. Let  $\omega_t^b = \frac{A_t^g}{A_t} \geq 0$  and  $\omega_t^e = \frac{N_t^g}{N_t} \geq 0$ . Then  $a_t^g = \omega_t^b a_t$  is the quantity of government-owned capital in an individual bank's balance sheet, and  $n_t^g = \omega_t^e n_t$  public funding allocated to non-financial firms. Also  $R_t^{gb} = (\omega_t^b / Q_t^b) R_t^b$  and  $R_t^{ge} = (\omega_t^e / Q_t^e) R_t^e$  are the (expected) shares of the proceeds going to the government in the banking sector and in the non-financial corporate sector, respectively.

The optimal financing contract solves the following program:

$$\max_{\{i_t, a_t, a_t^g, n_t^g, d_t, R_t^e, R_t^b, R_t^{gb}, R_t^{ge}, R_t^w, m_t\}} q_t p_H R_t^e i_t$$

subject to the entrepreneur's and her banker's incentive constraints (9) and (10), the depositors' and the banker's participation constraints (11) and (12)), two (modified) resource constraints for investment inputs and outputs

$$a_t + a_t^g + d_t - m_t i_t \geq i_t - n_t - n_t^g, \quad (56)$$

$$R \geq R_t^e + R_t^b + R_t^{gb} + R_t^{ge} + R_t^w. \quad (57)$$

and the equations characterizing the size of government capital injections

$$a_t^g = \omega_t^b a_t \quad (58)$$

$$n_t^g = \omega_t^e n_t \quad (59)$$

and the terms of bank recapitalization

$$R_t^{gb} = \frac{\omega_t^b}{Q_t^b} R_t^b \quad (60)$$

$$R_t^{ge} = \frac{\omega_t^e}{Q_t^e} R_t^e \quad (61)$$

Substitution of  $R_t^b = (1 + r_t^d) m_t / (q_t \Delta p)$ ,  $R_t^e = b(m_t) / (q_t \Delta p)$ , and equations (60) and (61), into the return-sharing constraint (57) shows that depositors can be promised at most

$$R_t^w = R - \frac{\left(1 + \frac{\omega_t^b}{Q_t^b}\right) (1 + r_t^d) m_t + \left(1 + \frac{\omega_t^e}{Q_t^e}\right) b(m_t)}{q_t \Delta p}. \quad (62)$$

Substituting (62) for the depositor's participation constraint (11) yields

$$p_H \left\{ q_t R - \frac{\left[ \left(1 + \frac{\omega_t^b}{Q_t^b}\right) (1 + r_t^d) m_t + \left(1 + \frac{\omega_t^e}{Q_t^e}\right) b(m_t) \right]}{\Delta p} \right\} = (1 + r_t^d) \frac{d_t}{i_t}. \quad (63)$$

Next, we combine the banker's incentive constraint (10) with his participation constraint (12), the input resource constraint (13), and the size of government's capital injections (58) and (59) to obtain

$$\frac{d_t}{i_t} = 1 + m_t - (1 + \omega_t^b) \frac{p_H}{\Delta p} \left( \frac{1 + r_t^d}{1 + r_t^a} \right) m_t - (1 + \omega_t^e) \frac{n_t}{i_t}. \quad (64)$$

Then combining (63) and (64), and noting that  $Q_t^b = (1 + r^a) / (1 + r^{ga})$  and  $Q_t^e = (1 + r^e) / (1 + r^{ge})$ , shows that the program boils down to

$$\max_{m_t \geq 0} \frac{(1 + \omega_t^e) b(m_t)}{\widehat{g}(r_t^a, r_t^d, r_t^{ga}, r_t^{ge}, q_t, m_t)}, \quad (65)$$

where

$$\begin{aligned} \widehat{g}(r_t^a, r_t^d, r_t^{ga}, r_t^{ge}, q_t, m_t) &= \left(1 + \omega_t^e \frac{1 + r_t^{ge}}{1 + r_t^e}\right) \frac{p_H}{\Delta p} b_t(m_t) \\ &+ (1 + r_t^d) \left[1 + \frac{p_H}{\Delta p} \left(1 - \frac{1 + r_t^d}{1 + r_t^a}\right) + \omega_t^e \frac{p_H}{\Delta p} \left(\frac{r_t^{ga} - r_t^d}{1 + r_t^a}\right)\right] m_t - \rho_t \end{aligned}$$

is inverse firm leverage. The unique interior solution to the problem (65) is

$$m_t^* = \frac{\gamma \rho_t}{1 + \frac{p_H}{\Delta p} \left(1 - \frac{1+r_t^d}{1+r_t^a}\right) + \omega_t^b \frac{p_H}{\Delta p} \left(\frac{r_t^{ga}-r_t^d}{1+r_t^a}\right)}. \quad (66)$$

On the other hand, the banker's incentive and participation constraints (10) and (12) (together with symmetry condition (20)) imply that in equilibrium bankers' monitoring intensity is still also characterized by (21). Then combining (21) and (66) we get a formula for the return to banker-owned capital:

$$1 + r_t^{a*} = \left[ \frac{\left(1 + \gamma \rho_t \frac{I_t}{A_t}\right) (1 + r_t^d) - \omega_t^b (r_t^{ga} - r_t^d)}{1 + \frac{\Delta p}{p_H}} \right] \quad (67)$$

Also, plugging (67) into (21) yields

$$\begin{aligned} m_t^* &= \left[ \frac{\left(1 - \omega_t^b \frac{r_t^{ga}-r_t^d}{1+r_t^d}\right) \frac{A_t}{I_t} + \gamma \rho_t}{1 + \frac{p_H}{\Delta p}} \right] \\ &= \left(1 + \frac{p_H}{\Delta p}\right)^{-1} \left( \frac{A_t - \left(\frac{r_t^{ga}-r_t^d}{1+r_t^d}\right) A_t^g}{I_t} + \gamma \rho_t \right) \end{aligned} \quad (68)$$

Next, we study aggregate investment and leverage. Equations (56), (58), (59) and (20) imply that

$$\frac{D_t}{I_t} = 1 + m_t^* - \frac{(1 + \omega_t^b) A_t + (1 + \omega_t^e) N_t}{I_t}. \quad (69)$$

Next, applying the aggregation/symmetry condition to (63), and plugging in expressions (67), (68) and (69), allows us to solve for

$$1 + r_t^e = \left( \left( (1 - \gamma) \rho_t \frac{I_t}{N_t} + 1 \right) (1 + r_t^d) - \omega_t^e (r_t^{ge} - r_t^d) \right) \quad (70)$$

Then, substituting equations (18)), (21), (67), (70) and (69) for equation

(63) yields, after some algebra,

$$\begin{aligned}
& \left( \frac{A_t - \left( \frac{r_t^{ga} - r_t^d}{1 + r_t^d} \right) A_t^g}{I_t^*} + \gamma \rho_t \right)^\gamma \left( \frac{N_t - \left( \frac{r_t^{ge} - r_t^d}{1 + r_t^d} \right) N_t^g}{I_t^*} + (1 - \gamma) \rho_t \right)^{1-\gamma} \\
&= \left( \frac{p_H}{\Delta p} \frac{\Gamma}{(1 + r_t^d)} \right)^{1-\gamma} \left( 1 + \frac{p_H}{\Delta p} \right)^\gamma \tag{71}
\end{aligned}$$

Equation (71) implicitly determines the aggregate investment level  $I_t^*$  in the economy, when both banks and non-financial firms have been recapitalized by the government. Quite naturally, setting  $N_t^g = 0$  or  $A_t^g = 0$  gives the aggregate investment level, when only banks or only non-financial corporations have been recapitalized

## B.2 The dynamics of banker-owned capital

Assume that there is an investment shock, so that the share of  $p_H (1 + \varepsilon_t)$  projects succeed, and aggregate revenues from the projects is  $p_H (1 + \varepsilon_t) R I_t$ . The sum  $p_H (1 + \varepsilon_t) R_t^e I_t$  is given to entrepreneurs, and  $p_H (1 + \varepsilon_t) R_t^{ge} I_t$  to the government, while depositors get  $(1 + r_t^d) D_t$ . What remains goes to the bank, which sum is then divided between the bankers ( $\tilde{R}_t^b$ ) and the government ( $\tilde{R}_t^{ga}$ ):

$$p_H (1 + \varepsilon_t) \left( \tilde{R}_t^b + \tilde{R}_t^{ga} \right) I_t = p_H (1 + \varepsilon_t) (R - R_t^e - R_t^{ge}) I_t - (1 + r_t^d) D_t \tag{72}$$

Next, note the government has bought bank equity at unit price  $Q_t^b$ , and it owns  $A_t^g / Q_t^b$  bank shares. Since bankers' revenues and government's revenues are proportional to their respective ownership shares, one can conclude that the ratio  $\tilde{R}_t^g / \tilde{R}_t^b$  is the same as given above in equation (60):  $\tilde{R}_t^g / \tilde{R}_t^b = A_t^g / (Q_t^b A_t)$ . Plugging this into (72), one can show that the stochastic rate of return to banker-owned capital is

$$1 + \tilde{r}_t^a = p_H (1 + \varepsilon_t) \tilde{R}_t^b \frac{I_t}{A_t} = (1 + r_t^a) (1 + \varepsilon_t) + (1 + r_t^d) \frac{D_t}{A_t + A_t^g / Q_t^b} \varepsilon_t \tag{73}$$



Here we have used the fact that the expected rate of banker-owned capital  $(1 + r_t^a)$  (eq. (67)) can also be expressed as

$$1 + r_t^a = \frac{p_H (R - R_t^e - R_t^{ge}) I_t - (1 + r_t^d) D_t}{A_t + A_t^g / Q_t^b}$$

Then the evolution of banker-owned capital is given by

$$\begin{aligned} A_{t+1}(\varepsilon_t) &= A_t \lambda^b \left( \frac{r_{t+1}^K + (1 - \delta) q_{t+1}}{q_t} \right) (1 + \tilde{r}_t^a) \\ &= A_t \lambda^b \left( \frac{r_{t+1}^K + (1 - \delta) q_{t+1}}{q_t} \right) \left[ (1 + r_t^a) (1 + \varepsilon_t) + \frac{(1 + r_t^d) D_t}{A_t + A_t^g / Q_t^b} \varepsilon_t \right]. \end{aligned}$$

To make this equation comparable to equation (35), we must impose  $r_t^{d*} = 0$ . This yields equation (39) of the main text.

### B.3 Proof of Proposition 4

The general aim here is to find a set of undominated public policies  $(A^g, N^g)$ , and to link the desired structure of public funding to the overall size of the program,  $F = A^g + N^g$ .

The proof consists of three steps. In Step 1 we explain what we mean by undominated policies  $(A^g, N^g)$ . In Step 2 we show that the set of undominated policies can be characterized by the ratio of benefit ratios to cost ratios ( $BCR$ ), discussed in the main text. We also show that there are three types of solutions, or three regimes, corresponding to bank funding ( $A^g > 0, N^g = 0$ ), firm funding ( $A^g = 0, N^g > 0$ ) and mixed funding ( $A^g > 0, N^g > 0$ ). In Step 3 we finally form a mapping between the aggregate scale of public funding  $F$  and the structure of undominated policies  $(A^g, N^g)$ : for each level of aggregate funding  $F$ , there is a unique way to divide the public resources between  $A^g$  and  $N^g$ , such that the policy mix  $(A^g, N^g)$  is not dominated by some other combination of policies  $(A^{g'}, N^{g'})$ . Notice that here in general  $A^g + N^g = F \neq F' = A^{g'} + N^{g'}$ . In words, the candidate policy  $(A^g, N^g)$  needs to be undominated by any alternative policy package  $(A^{g'}, N^{g'})$ , of arbitrary aggregate size  $F'$ .

*Step 1: Defining undominated policies*

Assume that the economy is initially in a steady state. We consider two possible scenarios. 1) Normal times: the economy is not hit by an investment shock ( $\varepsilon_t = 0$ ). 2) Crisis: the economy is hit by a negative investment shock ( $\varepsilon_t < 0$ ). We do not (have to) specify the exact size of the negative shock or the probability of the crisis.

Let us denote the discounted sum of present and future household utility in the normal times scenario by  $V^N = V^N(A^g, N^g; \varepsilon_t < 0, \cdot)$ . Likewise we denote the discounted sum of present and future household utility in the crisis scenario by  $V^C = V^C(A^g, N^g; \varepsilon_t = 0, \cdot)$ . As discussed in the main text (Section 6.3), public policies affect the economy through two channels only: 1) In the normal times scenario, public funding distorts the economy by blunting incentives and lowering investments  $I(A^g, N^g)$ . 2) In the crisis scenario public funding not only distorts the economy but also dampens the effect of the negative shock by lowering the bank leverage accelerator  $BL(A^g, N^g)$ . Hence we can write

$$\begin{aligned} V^N &= V^N(I(A^g, N^g); \varepsilon_t = 0, \cdot) \\ V^C &= V^C(I(A^g, N^g), BL(A^g, N^g); \varepsilon_t < 0, \cdot) \end{aligned}$$

Next, our task is to find a set of undominated policies  $(A^g, N^g)$ . In other words we want to find policies  $(A^g, N^g)$  such that there do not exist alternative policies  $(A^{g'}, N^{g'})$  that would dominate  $(A^g, N^g)$ . More formally:

$$\begin{aligned} \text{Find } A^g &\geq 0, N^g \geq 0 \text{ such that } \nexists A^{g'}, N^{g'} \\ V^N(I(A^{g'}, N^{g'}); \varepsilon_t = 0, \cdot) &\geq V^N(I(A^g, N^g); \varepsilon_t = 0, \cdot) \\ V^C(I(A^{g'}, N^{g'}), BL(A^{g'}, N^{g'}); \varepsilon_t, \cdot) &\geq V^C(I(A^g, N^g), BL(A^g, N^g); \varepsilon_t, \cdot), \forall \varepsilon_t < 0 \end{aligned}$$

*Step 2: Undominated policies can be characterized by BCR*

We can find the set of undominated policies in the following way: We choose a target level  $\overline{BL}$  for bank leverage. Then we find a policy combination  $(A^g, N^g)$  that minimizes distortions, or equivalently maximizes  $I(A^g, N^g)$

subject to  $BL(A^g, N^g) = \overline{BL}$ . More formally

$$\begin{aligned} & \max_{A^g, N^g} I(A^g, N^g) \\ & \text{subject to} \\ & BL(A^g, N^g) = \overline{BL}, \quad A^g \geq 0, N^g \geq 0 \end{aligned}$$

The corresponding *Lagrangian* is

$$\mathcal{L} = I(A^g, N^g) + \lambda_1 [BL(A^g, N^g) - \overline{BL}] + \lambda_2 A^g + \lambda_3 N^g$$

where  $\lambda_1$ ,  $\lambda_2$  and  $\lambda_3$  are Lagrangian multipliers. The first order conditions with respect to  $A^g$  and  $N^g$  are

$$\frac{\partial I(A^g, N^g)}{\partial A^g} + \lambda_1 \frac{\partial BL(A^g, N^g)}{\partial A^g} + \lambda_2 = 0 \quad (74)$$

$$\frac{\partial I(A^g, N^g)}{\partial N^g} + \lambda_1 \frac{\partial BL(A^g, N^g)}{\partial N^g} + \lambda_3 = 0 \quad (75)$$

The Kuhn-Tucker conditions associated with the constraints  $A^g \geq 0$  and  $N^g \geq 0$  are

$$\begin{aligned} \lambda_2 &= 0 \text{ if } A^g > 0, \quad \lambda_2 > 0 \text{ if } A^g = 0 \\ \lambda_3 &= 0 \text{ if } N^g > 0, \quad \lambda_3 > 0 \text{ if } N^g = 0 \end{aligned}$$

There are three types of solutions, or three regimes:

i) If  $A^g > 0$  and  $N^g = 0$ , we have  $\lambda_2 > 0$ ,  $\lambda_3 = 0$ . Then dividing (74) by (75) gives, after some straightforward algebra

$$\frac{1}{BCR(A^g, N^g)} = \frac{CR(A^g, N^g)}{BR(A^g, N^g)} = 1 + \frac{\lambda_2}{\lambda_1} \left[ \frac{\partial BL(A^g, N^g)}{\partial A^g} \right]^{-1} < 1$$

where the inequality follows, since  $\lambda_2 > 0$ ,  $\lambda_1 > 0$  and  $\frac{\partial BL(A^g, N^g)}{\partial A^g} < 0$ .

ii) If  $A^g > 0$  and  $N^g > 0$ , we have  $\lambda_2 = 0$ ,  $\lambda_3 = 0$ . Then dividing (74) by (75) gives

$$BCR(A^g, N^g) = 1$$

iii) If  $A^g = 0$  and  $N^g > 0$ , we have  $\lambda_2 = 0$ ,  $\lambda_3 > 0$ . Then dividing (75) by (74) gives

$$BCR(A^g, N^g) = 1 + \frac{\lambda_3}{\lambda_1} \frac{\partial BL(A^g, N^g)}{\partial N^g} < 1$$

where the inequality follows since  $\lambda_3 > 0$ ,  $\lambda_1 > 0$  and  $\frac{\partial BL(A^g, N^g)}{\partial N^g} < 0$ .

*Step 3: Undominated policies and the aggregate scale of public funding  $F$*

Here we demonstrate how the desired structure of public funding is linked to the overall size of the program,  $F = A^g + N^g$ . Completing this final step of the proof also leads to the results stated in Proposition 4, items *a*, *b*, and *c*.

In the analysis that follows, it is useful to note that in addition to the expression (42) in the main text,  $BCR$  can be expressed in two slightly different, but equivalent, forms

$$BCR = BCR^*(A^g, F) = \left( 1 - \left( \frac{(D - F) / (Q^b A)}{1 + A^g / (Q^b A)} \right) \right) \left| \frac{dA}{dN} \right|_{I^*} \quad (76)$$

$$BCR = BCR^{**}(N^g, F) = \left( 1 + \frac{(D - F) / (Q^b A)}{1 + (F - N^g) / (Q^b A)} \right) \left| \frac{dA}{dN} \right|_{I^*} \quad (77)$$

a) Assume that  $F \leq F_L$ . Now using (76), one can show that  $BCR^*(A^g, F) \geq 1$  for all  $A^g \leq F$ . Hence it optimal for the government to target only banks ( $A^g = F, N^g = 0$ ), if  $F \leq F_L$ . By contrast, if  $F > F_L$ , (76) implies that  $BCR^*(A^g = F, F) < 1$ , and it is not optimal for the government to target only banks.

b) Assume that  $F \in (F_L, F_U)$ . In the (putative) optimum, both banks and non-financial firms are capitalized, meaning that we must have  $BCR = 1$ . Using the equation  $A^g + N^g = F$  with either (76) or (77) one can show that  $BCR = 1$  if and only if  $A^g$  and  $N^g$  are given by (43). Moreover, using (76) one can show that  $\partial BCR / \partial A^g < 0$  while using (77) shows that  $\partial BCR / \partial N^g > 0$ , when  $F = A^g + N^g$  is kept constant; hence the allocation characterized by (43) is indeed the unique undominated policy combination, given aggregate funding scale  $A^g + N^g = F$ .

c) Assume that  $F \geq F_L$ . Now using (77), one can show that  $BCR^{**}(N^g, F) \leq 1$  for all  $N^g \leq F$ . Hence it is optimal for the government to target only firms ( $A^g = 0, N^g = F$ ), if  $F \geq F_U$ . By contrast, if  $F < F_U$ , (77) implies that  $BCR^*(N^g = F, F) > 1$ , and it is not optimal for the government to target only firms.

## B.4 Further interpretation of Proposition 4

Evidently, the finding that bank capitalization is typically favored over firm capitalization depends on the calibration. Nevertheless, this result holds quite generally in our model. The benefit calculus, which favors targeting banks, hinges on bank leverage — in particular we have  $BR^{\max} = BR(A^g = 0, N^g = 0) = 1 + D/(Q^b A)$ . On the other hand, injecting a certain amount of capital into banks, rather than firms, distorts the economy more, since bank capital is scarce compared to firm capital. But these two things, high bank leverage and the scarcity of bank capital, are not independent of each other but are instead closely linked. To see the linkage between the benefit calculus and the cost calculus more clearly, let us rewrite the term  $CR = |dN/dA|_{I^*}$  (essentially measuring the relative scarcity of bank capital, and capturing the gist of the cost calculus) with the help of steady state financial variables. Using the equations of Appendix C.2 one can show that

$$\left| \frac{dN}{dA} \right|_{I^*} \approx \frac{r^a}{r^e} \left( 1 + \frac{CORB}{\bar{r}^a} \left( 1 + \frac{D}{A} \right) \right)$$

From this equation, one can see that the measure of the relative scarcity of bank capital ( $| \frac{dN}{dA} |_{I^*}$ ) is related to bank leverage (the term  $(1 + \frac{D}{A})$ ). Next notice that leverage is multiplied by the term  $\frac{CORB}{r^a}$ , where  $CORB = \frac{mI}{A+D-mI}$  is a measure of banks' monitoring costs, relative to banks' assets. Also the term  $\frac{CORB}{r^a}$  has a rather natural interpretation: monitoring costs constitute a part of the cost of financial intermediation, and unlike the return to bank capital ( $r^a$ ), this part of the cost of intermediation does not translate into new banker-owned capital. As argued in Section 3, this is one reason why bank capital is scarce in equilibrium. A key point, however, is that the term

$(\frac{CORB}{r^e})$  is typically quite small; in our baseline calibration  $(\frac{CORB}{r^a}) = 0.11$  while  $(\frac{r^a}{r^e})(\frac{CORB}{r^a}) = (\frac{CORB}{r^e}) = 0.33$  (both values are clearly less than 1). From this discussion one can see that quite generally we have  $BR^{\max} > CR$ , so that  $BCR > 1$  when  $F$  is small enough.

## C Technical appendix

### C.1 Steady-state

We derive the steady-state of the financial block of the model in four steps:

1. The law of motion of  $A_t$  is

$$A_{t+1} = \lambda^b \left( \frac{r_{t+1}^K + (1 - \delta) q_{t+1}}{q_t} \right) p_H q_t R_t^b I_t \quad (78)$$

and the law of motion of  $N_t$  is

$$N_{t+1} = \lambda^e \left( \frac{r_{t+1}^K + (1 - \delta) q_{t+1}}{q_t} \right) p_H q_t R_t^e I_t \quad (79)$$

Then in steady state we get

$$\frac{A}{N} \equiv \nu = \frac{\lambda^b R^b}{\lambda^e R^e} = \frac{\lambda^b m}{\lambda^e b} \quad (80)$$

where the last form follows since

$$R^b = m / (q \Delta p), \quad R^e = b / (q \Delta p)$$

2. Denote

$$H_t = A_t + N_t$$

and combine (78) and (79). We get

$$H_{t+1} = \left( \frac{r_{t+1}^K + (1 - \delta) q_{t+1}}{q_t} \right) p_H q_t \frac{H_t}{G_t} (\lambda^b R_t^b + \lambda^e R_t^e)$$

(since  $I_t = H_t/G_t$ ). Thus in steady state

$$1 = \left( \frac{r^K + (1 - \delta)q}{q} \right) p_H q \frac{1}{G} (\lambda^b R^b + \lambda^e R^e)$$

Workers' Euler equation implies that in steady state

$$1 = \beta \left( \frac{r^K + (1 - \delta)q}{q} \right).$$

Combine

$$R^b = m / (q\Delta p), \quad R^e = b / (q\Delta p),$$

with above to obtain

$$G = \frac{1}{\beta} \frac{p_H}{\Delta p} (\lambda^b m + \lambda^e b). \quad (81)$$

3. Use the equilibrium relations

$$m_t = \frac{\frac{\Delta p}{p_H}}{1 + \frac{\Delta p}{p_H}} \left( \gamma \rho_t + \frac{A_t}{I_t} \right) = \frac{\frac{\Delta p}{p_H}}{1 + \frac{\Delta p}{p_H}} (\gamma \rho_t + \mu_t G_t) \quad (82)$$

and

$$\begin{aligned} m_t &= \frac{\Delta p}{p_H} \left( (1 - \gamma) \rho_t + \frac{N_t}{I_t} \right) \\ &= \frac{\Delta p}{p_H} ((1 - \gamma) \rho_t + (1 - \mu_t) G_t), \end{aligned} \quad (83)$$

where

$$\mu_t = \frac{A_t}{A_t + N_t} = \frac{\nu_t}{1 + \nu_t}.$$

Plug (81) into (82) and (83). Then in steady-state we have

$$m = \frac{\frac{\Delta p}{p_H}}{1 + \frac{\Delta p}{p_H}} \left( \gamma \rho + \frac{\nu}{1 + \nu} \frac{1}{\beta} \frac{p_H}{\Delta p} (\lambda^b m + \lambda^e b) \right) \quad (84)$$

and

$$b = \frac{\Delta p}{p_H} \left( (1 - \gamma) \rho + \frac{1}{1 + \nu} \frac{1}{\beta} \frac{p_H}{\Delta p} (\lambda^b m + \lambda^e b) \right). \quad (85)$$

From (80) we get

$$m = \frac{\lambda^e}{\lambda^b} \nu b \quad (86)$$

and plugging this into (84) and (85) yields

$$\frac{\lambda^e}{\lambda^b} \nu b = \frac{\frac{\Delta p}{p_H}}{1 + \frac{\Delta p}{p_H}} \left( \gamma \rho + \nu \frac{1}{\beta} \frac{p_H}{\Delta p} \lambda^e b \right)$$

and

$$b = \frac{\Delta p}{p_H} \left( (1 - \gamma) \rho + \frac{1}{\beta} \frac{p_H}{\Delta p} \lambda^e b \right). \quad (87)$$

Solving  $\rho$  from (87) yields

$$\rho = \frac{p_H}{\Delta p} \left( 1 - \frac{\lambda^e}{\beta} \right) \left( \frac{b}{1 - \gamma} \right) \quad (88)$$

Finally plugging (88) into (84) gives

$$\frac{\lambda^e}{\lambda^b} \nu b = \frac{1}{1 + \frac{\Delta p}{p_H}} \left( \left( 1 - \frac{\lambda^e}{\beta} \right) \frac{\gamma}{1 - \gamma} + \nu \frac{\lambda^e}{\beta} \right) b \quad (89)$$

Evidently  $b$  cancels out from (89), and the equation can be solved for  $\nu$

$$\nu = \frac{\lambda^b}{\lambda^e} \left( \frac{1 - \frac{\lambda^e}{\beta}}{1 + \frac{\Delta p}{p_H} - \frac{\lambda^b}{\beta}} \right) \left( \frac{\gamma}{1 - \gamma} \right). \quad (90)$$

4. Using the relation (86) together with the monitoring technology

$$b = \Gamma m^{-\frac{\gamma}{1-\gamma}} \Leftrightarrow m^\gamma b^{1-\gamma} = \Gamma^{1-\gamma}$$

we get

$$b = \left( \frac{\lambda^b}{\lambda^e} \right)^\gamma \frac{\Gamma^{1-\gamma}}{\nu^\gamma} \quad (91)$$



and

$$m = \left( \frac{\lambda^e}{\lambda^b} \right)^{1-\gamma} \Gamma^{1-\gamma} \nu^{1-\gamma} \quad (92)$$

This allows us to write the steady-state of the financial block in a recursive form: Equation (90):

$$\nu = \frac{\lambda^b}{\lambda^e} \left( \frac{1 - \frac{\lambda^e}{\beta}}{1 + \frac{\Delta p}{p_H} - \frac{\lambda^b}{\beta}} \right) \left( \frac{\gamma}{1 - \gamma} \right).$$

Equation (91):

$$b = \left( \frac{\lambda^b}{\lambda^e} \right)^\gamma \frac{\Gamma^{1-\gamma}}{\nu^\gamma}.$$

Equation (92):

$$m = \left( \frac{\lambda^e}{\lambda^b} \right)^{1-\gamma} \Gamma^{1-\gamma} \nu^{1-\gamma}.$$

Equation (81):

$$G = \frac{1}{\beta} \frac{p_H}{\Delta p} (\lambda^b m + \lambda^e b).$$

Equation (88):

$$\rho = \frac{p_H}{\Delta p} \left( 1 - \frac{\lambda^e}{\beta} \right) \left( \frac{b}{1 - \gamma} \right).$$

To derive the rest of the steady-state system, we derive the steady state version of the net present value of investment project

$$\begin{aligned} \rho &= \Gamma \frac{p_H}{\Delta p} \left( \frac{1 - \frac{\lambda^b}{\beta} + \frac{\Delta p}{p_H}}{\gamma} \right)^\gamma \left( \frac{1 - \frac{\lambda^e}{\beta}}{1 - \gamma} \right)^{1-\gamma} \\ &= \Gamma \frac{p_H}{\Delta p} \nu^{-\gamma} \frac{1 - \frac{\lambda^e}{\beta}}{1 - \gamma} \left( \frac{\lambda^b}{\lambda^e} \right)^\gamma, \end{aligned}$$

Following from the definition of  $\rho_t$  and the assumption  $r^d = 0$ , the steady-state price of capital is given by

$$q = \frac{1 + \rho}{p_H R(1 + s)},$$

where  $s$  is a possible investment subsidy. We set  $s = \rho$  to obtain the same steady-state as for the RBC model. If  $s = 0$ , the steady-state levels of real variables would be below the corresponding RBC model.

Note that the steady-state real rate is  $r = 1/\beta - 1$ . Then the rental rate of capital is

$$r^K = q(r + \delta).$$

Finally, the steady-state real wage

$$W = (1 - \alpha) \left( \frac{r^K}{\alpha} \right)^{-\frac{\alpha}{1-\alpha}},$$

capital stock

$$K = \left[ \left( \frac{1 - \alpha}{\xi} \right) \left( \frac{r^K}{\alpha} \right)^{-\frac{\alpha+\phi}{1-\alpha}} \left( \frac{r^K}{\alpha} - \frac{\delta}{p_H R} \right)^{-\sigma} \right]^{\frac{1}{\phi+\sigma}},$$

hours worked

$$L = K \left( \frac{r^K}{\alpha} \right)^{\frac{1}{1-\alpha}},$$

output

$$Y = \frac{r^K K}{\alpha},$$

investments

$$I = \frac{\delta K}{p_H R},$$

consumption

$$C = Y - I,$$

bank capital

$$A = \frac{\nu}{1 + \nu} G I,$$

entrepreneurial capital

$$N = \frac{1}{1 + \nu} G I$$

and deposits

$$D = (1 + m - G) I.$$

## C.2 Calibration of the Financial Block

The calibration of the parameters of the financial block of the model is based on the following observables:

- *Excess* rate of return on bank capital  $r^a$
- *Excess* rate of return on entrepreneurial capital  $r^e$

In each period, bankers earn the gross rate of return  $(1 + r)(1 + r^a)$  and entrepreneurs earn the rate of return  $(1 + r)(1 + r^b)$ , where  $r$  is the real interest rate earned by workers.

- Non-financial firms' capital ratio

$$CRF = \frac{N}{I}$$

- Banks' capital ratio

$$CRB = \frac{A}{A + D - mI} = \frac{A}{I - N}$$

Note that  $A + D - mI$  is the amount of funds that the banks have allocated to the investment projects; here we have subtracted the monitoring costs of the banks  $mI$  from the amount of total funds  $A + D$ .

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Notice also the difference between the balance sheets of non-financial firms and banks. Non-financial firms have funds from bankers and outsiders (i.e. depositors), plus entrepreneurs' own capital, in their balance sheets. The grand total is  $I$ . Banks have funds from bankers and outsiders (depositors), and the aggregate amount of funds is  $I - N$ .

- Banks' monitoring costs, as a ratio of banks' assets

$$CORB = \frac{mI}{I - N}$$

---

<sup>20</sup>Having the term  $cI$  facilitates finding the analytical formulation for all parameters.

The financial parameters to be calibrated are

1. The exit rate of bankers  $\lambda^b$

$$\lambda^b = \frac{\beta}{1 + r^a} = \frac{1}{(1 + r^a)(1 + r)}$$

2. The exit rate of entrepreneurs  $\lambda^e$

$$\lambda^e = \frac{\beta}{1 + r^e} = \frac{1}{(1 + r^e)(1 + r)}$$

3. The (relative) difference in the success probabilities of good and bad projects  $\frac{\Delta p}{p_H}$  (only this ratio, rather than the probabilities  $p_H$  and  $p_L$  as such, is relevant here),

$$\frac{\Delta p}{p_H} = \frac{CORB}{CRB(1 + r^a)}$$

4. The elasticity of the monitoring function  $\frac{\gamma}{1-\gamma}$ ,

$$\gamma = \frac{r^a CRB + CORB}{r^e \frac{CRF}{1-CRF} + r^a CRB + CORB}$$

Notice that  $\frac{CRF}{1-CRF} = \frac{N}{I-N}$  is the ratio of entrepreneurial capital to non-entrepreneurial capital in non-financial firms' balance sheets. Then  $\gamma$  can be re-expressed in yet another way

$$\begin{aligned} \gamma &= \frac{r^a A + mI}{r^e N + r^a A + mI} \\ &= \frac{\text{banks' profits} + \text{banks' monitoring costs}}{\text{entrepreneurs' profits} + \text{banks' profits} + \text{banks' monitoring costs}} \end{aligned}$$

5. The coefficient of the monitoring function is given by  $m^\gamma b^{1-\gamma} = \Gamma^{(1-\gamma)}$ , then

$$\Gamma = \left( \frac{1 + r^e}{1 + r^a} \right) \left( \frac{CRF}{CRB} \right) (1 - CRF)^{\frac{\gamma}{1-\gamma}} CORB^{\frac{1}{1-\gamma}}.$$

### C.3 Ruling out the corner solution

In this appendix we study the conditions under which the no monitoring corner solution,  $m_t = 0$ ,  $b(m_t) = \bar{b}$ , can be ruled out. Assume that a firm chooses *not* to be monitored:  $m_t = 0$ . According to equations (15) and (16), the maximum leverage,  $i_t/n_t$ , it can obtain is given by

$$\frac{i_t}{n_t} = \frac{1}{g(r_t^a, r_t^d, q_t; m_t = 0, b_t = \bar{b})} = \frac{1}{\frac{p_H}{\Delta p} \bar{b} - \rho_t}.$$

Under this choice, the expected rate of return on entrepreneurial capital,  $\hat{r}_t^e$ , is given by

$$\hat{r}_t^e = \frac{\frac{p_H}{\Delta p} \bar{b}}{g(r_t^a, r_t^d, q_t; m_t = 0, b_t = \bar{b})} = \frac{\rho_t}{\frac{p_H}{\Delta p} \bar{b} - \rho_t}.$$

To rule out the corner solution, we must have

$$\hat{r}_t^e < r_t^e, \tag{93}$$

where  $r_t^e$  is the expected rate of return on entrepreneurial capital, if the entrepreneur chooses the interior solution  $m_t = m_t^*$ . In particular, the condition (93) should apply in the steady state, so that we get the condition

$$\bar{b} \geq \frac{\Delta p}{p_H} \frac{1 + r^e}{r^e} \rho.$$

In steady state the rate of return corresponding to the interior solution is

$$r^e = \frac{\beta}{\lambda^e} - 1,$$

and the net present value of the investment project

$$\rho = \frac{p_H}{\Delta p} \frac{\Gamma^{1-\gamma}}{1-\gamma} \left(1 - \frac{\lambda^e}{\beta}\right) \hat{v}^{-\gamma},$$

where

$$\hat{v} \equiv \frac{\lambda^e}{\lambda^b} \frac{A}{N} = \frac{\gamma}{1-\gamma} \frac{1 - \frac{\lambda^e}{\beta}}{1 - \frac{\lambda^b}{\beta} + \frac{\Delta p}{p_H}}.$$

Consequently, the condition can be expressed as

$$\bar{b} \geq \frac{\Gamma^{1-\gamma}}{1-\gamma} \hat{\nu}^{-\gamma}. \quad (94)$$

In addition, we seek the condition that guarantees that it is optimal to choose the "good" project and the (interior) level of monitoring  $m_t^*$ , rather than the "bad" project with the maximum level of private payoffs  $\bar{b}$  and no monitoring. For this condition to hold in the steady state, we must have

$$\begin{aligned} p_H R - m^* &\geq p_L R + \bar{b} \iff \\ \bar{b} &\leq \frac{\Delta p}{p_H} p_H R - m^*. \end{aligned} \quad (95)$$

To rule out a corner solution, we must find a value of  $\bar{b}$  that satisfies both (94) and (95). Such a value  $\bar{b}$  exists if and only if

$$(\Gamma \hat{\nu})^{1-\gamma} \left( \frac{1}{1-\gamma} + \frac{1}{\hat{\nu}} \right) < \frac{\Delta p}{p_H} p_H R, \quad (96)$$

where we have utilized the steady-state equation  $m^* = (\Gamma \hat{\nu})^{1-\gamma}$ . The condition (96) can be further rewritten with the help of observable variables.

$$\left( 1 + \left( \frac{1 - CRF}{r^e CRF} \right) (r^a CRB + CORB) \right) (1 - CRF) CRB (1 + r^a) + (1 + r^e) CRF < 1 \quad (97)$$

With our calibration, the above condition (96) - or alternatively and equivalently (97) is satisfied.

## C.4 A condition for market discipline and endogenous leverage

In this appendix we derive the condition for market discipline. This rules out the situation where bankers can pay depositors (in full) in the no-monitoring case where entrepreneurs choose a project with a lower success probability

$p_L$  (the "bad" project). *Market discipline condition* is given by

$$p_L q_t (R - R_t^e) I_t < D_t, \quad (98)$$

where the left-hand side gives the banks' revenue in case entrepreneurs choose the "bad" project. We show that the market discipline condition can be rewritten with the help of observable variables: (98) is equivalent to (99)

$$\frac{((1 + r^a) CRB)^2}{CORB(1 + r^a CRB + CORB)} < 1. \quad (99)$$

Getting from (98) to (99) involves several steps:

1. Divide both sides of (98) by  $N_t$ , and divide and multiply the left-hand side by  $p_H$  to obtain

$$\frac{p_L}{p_H} p_H q_t (R - R_t^e) \frac{I_t}{N_t} < \frac{D_t}{N_t} \quad (100)$$

Then use the following results, definitions and normalizations

$$p_H q_t R_t^e \frac{I_t}{N_t} = 1 + r_t^e, \quad p_H R = 1$$

to rewrite (100) as

$$\frac{p_L}{p_H} \left( \frac{q_t}{CRF_t} - 1 + r_t^e \right) < \frac{D_t}{N_t} \quad (101)$$

2. Notice that

$$\frac{D_t}{N_t} = \frac{D_t}{I_t} \frac{I_t}{N_t} \quad (102)$$

and use the resource constraint

$$A_t + N_t + D_t = I_t (1 + m_t)$$

to obtain

$$\frac{D_t}{I_t} = 1 + m_t - \frac{N_t}{I_t} - \frac{A_t}{I_t}$$

When bankers do not monitor,  $m_t = 0$ . Since we assume that bankers can hide the funds reserved for monitoring  $m_t I_t$ , they cannot be used in financing the investment projects. Then rewritten

$$\frac{A_t}{I_t} = \frac{A_t}{I_t - N_t} \frac{I_t - N_t}{I_t} = CRB_t(1 - CRF_t)$$

where the latter equation holds due to the definitions above. Notice that

$$m_t = \frac{m_t I_t}{I_t - N_t} \frac{I_t - N_t}{I_t} = CORB_t(1 - CRF_t).$$

Given these results, we obtain following

$$\begin{aligned} \frac{D_t}{I_t} &= 1 + m_t - \frac{N_t}{I_t} - \frac{A_t}{I_t} \\ &= 1 - CRF_t - (CRB_t - CORB_t)(1 - CRF_t). \end{aligned} \quad (103)$$

Then plugging (103) into (102) and using the fact that  $I_t/N_t = 1/CRF_t$  we get

$$\frac{D_t}{N_t} = \frac{1 - CRF_t - (CRB_t - CORB_t)(1 - CRF_t)}{CRF_t}, \quad (104)$$

and, finally, plugging (104) into (101), and slightly manipulating, yields

$$\frac{p_L}{p_H} (q_t - (1 + r_t^e) CRF_t) < (1 - CRF_t)(1 - CRB_t + CORB_t). \quad (105)$$

3. We need to express the price of capital  $q_t$  in terms of the observable measures used in the calibration. To do this first notice that

$$q_t = 1 + \rho_t \quad (106)$$

where  $\rho_t$  is the NPV of the project. Using results from appendices C.1 and A.6 one can show that

$$\rho = r^e CRF + (r^a CRB + CORB)(1 - CRF) \quad (107)$$



4. We plug the results (106) and (107) into (105) to obtain

$$\begin{aligned}
& \frac{p_L}{p_H} (1 + r^e CRF + (r^a CRB + CORB) (1 - CRF) - (1 + r_t^e) CRF) \\
& < (1 - CRF) (1 - CRB + CORB) \iff \\
& \frac{p_L}{p_H} (1 + r^a CRB + CORB) < 1 - CRB + CORB. \tag{108}
\end{aligned}$$

5. Finally, we first rewrite

$$\frac{p_L}{p_H} = 1 - \frac{\Delta p}{p_H}.$$

Noting that  $\frac{\Delta p}{p_H} = \frac{CORB}{CRB(1+r^a)}$ , equation (108) can be rewritten as

$$\begin{aligned}
& \left(1 - \frac{CORB}{CRB(1+r^a)}\right) (1 + r^a CRB + CORB) < 1 - CRB + CORB \iff \\
& (1 + r^a) CRB < \frac{CORB}{CRB(1+r^a)} (1 + r^a CRB + CORB) \\
& \iff \frac{((1 + r^a) CRB)^2}{CORB(1 + r^a CRB + CORB)} < 1.
\end{aligned}$$

Hence we have shown that (98) can be rewritten as (99).

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