Saving Wall Street or Main Street*

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February 15, 2016

Abstract

We build a dynamic stochastic general equilibrium model, where both the balance sheets of banks and the balance sheets of 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 rescue banks, and if resources are large enough, lend to firms too.

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Ripatti acknowledges financial support from Yrjö Jahnsson Foundation and OP Group Research Foundation. We thank Alice Albonico, Kevin Moran, Lauri Vilmi, Michal Andrle, John Tsoukalas, Efrem Castelnuovo, Martin Ellison, Marlène Isoré, Alessia Paccagnini and seminar participants at the HECER, the Bank of Finland, the Universities of St. Gallen, Padua, Hokkaido, Oxford, Pavia, Kyoto and Keio and at the IMF, Coucil for Budget Responsibility (Slovakia), ISCEF , EEA , Dynare and at XXIII International Rome Conference of Money, Banking and Finance for useful discussions and comments.

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 recent crisis, government capital injections to banks were close to five percent in the US (SIGTARP, 2014).[1] The Federal Reserve System also 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 to non-banks reached almost three percent of the GDP (Labonte, 2016).[2]

In this paper, we analyse capital injections from the government to the banking sector and direct public financing of non-financial firms in times of crisis. The main question we ask is the following: Suppose the government has decided to use a certain sum of money to provide funding to the private sector. How should these resources be allocated? Should the government target (only) banks or (only) non-financial firms, or maybe both?

We analyse these issues using a dynamic stochastic general equilibrium (DSGE) model with financial frictions, where balance sheets of both banks and non-financial firms play a role in macro-financial linkages. Our framework builds on the Holmstrom and Tirole (1997) model of financial intermediation. [3] In the DSGE models building on Holmstrom and Tirole (1997)

[1] 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.

[2] General Motors and Chrysler got direct government support. The FED created Commercial Paper Funding Facility (CPFF) and Term Asset-Backed Securities Loan Facility (TALF) programs. There programs targeted to provide liquidity to the securitization market and to the non-financial firms respectively.

[3] 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 inter-

(see Aikman and Paustian (2006), Faia (2010) and Meh and Moran (2010)[4]) 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 (=the 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.[5]

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, like 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 capital but also its composition 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

mediation 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.

[4]Early attempts to introduce a Holmstrom – Tirole type financial friction in macroeconomic models include Castrén and Takalo (2000) and Chen (2001).

[5]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.

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 smaller than what would maximize the investments and output. Also, a given change of 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 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 entrepreneurial capital.

Our model forms an attractive framework for studying government involvement in banks and in non-financial firms. We find that public funding gives rise to both social benefits and social costs. The benefits stem from the improved stability of the financial system and the macro economy. The social costs are related to diluted insider stakes and distorted incentives. Given the scarcity of bank capital, injecting a certain sum of public money into banks involves both larger social benefits (in the form of boosted shock cushions) and larger social costs (in the form of diluted stakes and blunted incentives) than direct funding of non-financial firms.

But should the government target banks or non-financial firms? Which policy option has the better cost-benefit ratio? The answer to this question depends on the size of government programs. If the amount of public funding is small or moderate, the government should invest all the money in banks: given the scarcity of bank capital, and high bank leverage, capital injections have a (very) large proportional effect on banks' shock cushions. To put it differently, with small and moderate sized capitalizations, the benefit calculus, favoring banks, trumps the cost calculus, favoring firms. However, if the total size of public programs is larger, the government should fund both banks and non-financial firms. This is also quite intuitive: 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. Then the benefit calculus, favoring banks, no longer trumps the cost calculus, favoring firms, but both sides of the cost-benefit analysis have to be considered: this is done by dividing public funds between banks and firms. In sum, we establish a pecking order of public interventions: the government should first capitalize banks and, if the size of public funding is large enough, expand its programmes to non-financial firms.

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 explain how we calibrate the model and in Section 6 we study the impulse responses of financial and macro variables to a number of shocks. In Section 7 we analyse capital injections and direct lending from the government to banks and firms. Finally, Section 8 concludes.

2 The Model

We consider a discrete time, infinite horizon economy that is 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, have temptation to choose less productive projects with higher non-verifiable returns. Second, bankers' monitoring can mitigate the entrepreneurs' moral hazard temptations but since the banks use deposits from the households to finance the 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, 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 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 return to their risky investments than workers earn to their deposits. Hence it is optimal for the household to let its entrepreneurs and bankers to keep building 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 a perfect consumption insurance against the risks entrepreneurs and bankers take. Therefore, all household members consume an equal amount in each period.

The problem of a representative household is

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

subject to a budget constraint:

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

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 intertemporal budget constraint (2). While being somewhat controversial the assumption facilitates comparison of our model with the standard RBC framework. We later elaborate the implications of this assumption.

Physical capital stock accumulates according to the law of motion

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

where I_t is the investment level in period t. This accumulation equation is standard save for the two parameters of the 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:

$$\frac{\xi L_t^{\phi}}{C_t^{-\sigma}} = W_t \tag{4}$$

and

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

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

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

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:

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

and

$$r_t^K = \alpha \frac{Y_t}{K_t}. \tag{8}$$

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 the intermediation of entrepreneurial finance only occurs 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 invests their funds directly in the projects of the 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 the projects of the 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 to Ri ($R > 1$) verifiable units of capital goods while failed projects yield nothing. The projects differ in their probability of success and the amount of non-verifiable revenues created by them. 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 amount of non-verifiable revenues bi, $b \in \left(0, \overline{b}\right]$, attached to them. Non-verifiable revenues are proportional to investment size as in Holmstrom and Tirole (1997).[6] 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.[7] 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 $q_t p_H R > \max\left\{1, q_t p_L R + \overline{b}\right\}$ 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 c $(c \geq 0)$ eliminates all bad projects where $b \geq b(c)$ from the entrepreneur's project choice set. The threshold level of non-verifiable revenues $b(c)$ is decreasing and convex in the monitoring intensity: $b'(c) \leq 0, b''(c) \geq 0$, and $\lim_{c \to \infty} b'(c) = 0$. As in Christiansen et al. (2012) monitoring consumes real resources (e.g., labor): to obtain monitoring intensity c, a bank must pay ci units of final goods to workers of its household. That is, the more a banker invests in monitoring the less his bank can lend to entrepreneurs.

[6] 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.

[7] One interpretatation 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 lower expected project returns in case diversion takes place.

Because of diminishing returns to monitoring investments, the banker will never want to eliminate all bad projects. Therefore, despite monitoring, entrepreneurs must be provided incentives to choose the good project. In sum, there are two moral hazard problems among different 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 the 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 from the project returns, maximizes the bank's profits by choosing monitoring intensity, c_t. Banks behave competitively. As a result, the banks offer the same contract that would be offered by a single bank that would maximize the entrepreneur's expected proftis. An optimal financing contract therefore solves the following program:

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

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

$$q_t p_H R_t^e i_t \geq q_t p_L R_t^e i_t + b\left(c_t\right) i_t, \tag{9}$$

$$q_t p_H R_t^b i_t \geq q_t p_L R_t^b i_t + \left(1 + r_t^d\right) c_t i_t, \tag{10}$$

the depositors' and the banker's participation constraints

$$q_t p_H R_t^w i_t \geq \left(1 + r_t^d\right) d_t, \tag{11}$$

$$q_t p_H R_t^b i_t \geq \left(1 + r_t^a\right) a_t, \tag{12}$$

and two resource constraints for the investment inputs and outputs

$$a_t + d_t - c_t i_t \geq i_t - n_t, \tag{13}$$

$$R \geq R_t^e + R_t^b + R_t^w. \tag{14}$$

Equations (13) and (14) mean that the aggregate supply of investment funds must satisfy their aggregate demand and equation and that the total returns must be enough to cover the total payments, respectively. Variable r_t^a featuring 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. In the first step we take the intensity of monitoring c_t and, by implication, the level of private revenues $b(c_t)$ as given and solve for the maximum size of the investment project i_t for a given level of entrepreneurial wealth n_t. As the second step, we solve for the equilibrium level of monitoring c_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. From the entrepreneur's and the banker's incentive constraint (9) and (10) we see that the entrepreneur and the banker must get no less than

$$R_t^e = \frac{b(c_t)}{q_t \Delta p} \tag{15}$$

and

$$R_t^b = \frac{\left(1+r_t^d\right) c_t}{q_t \Delta p} \tag{16}$$

respectively, in case of success, as otherwise they will misbehave. Substitution of equations (15) and (16) for the return-sharing constraint (14) shows that depositors can be promised at most

$$R_t^w = R - \frac{\left(1+r_t^d\right) c_t + b(c_t)}{q_t \Delta p}. \tag{17}$$

Substituting equation (17) for the depositor's participation constraint (11) yields

$$p_H \left\{ q_t R - \frac{\left[\left(1+r_t^d\right) c_t + b(c_t)\right]}{\Delta p} \right\} = \left(1+r_t^d\right) \frac{d_t}{i_t}. \tag{18}$$

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

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

which can be then substituted for equation (18). Solving the resulting equation for i_t gives

$$i_t = \frac{n_t}{g\left(r_t^a, r_t^d, q_t, c_t\right)} \tag{19}$$

where

$$g\left(r_t^a, r_t^d, q_t, c_t\right) = \frac{p_H b(c_t)}{\Delta p (1+r_t^d)} + \left[1 + \frac{p_H}{\Delta p}\left(1 - \frac{1+r_t^d}{1+r_t^a}\right)\right] c_t - \rho_t \tag{20}$$

is the inverse degree of leverage, i.e., the smaller is $g(\cdot)$, 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 (20) shows how agengy problems decrease leverage by discouraging participation of outside investors. These agency problems can be mitigated by increasing monitoring. However, the second term shows how more intense monitoring also has two negative effects on leverage since it consumes resources that could have otherwise 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 term in the square brackets, respectively (note that in equilibrium we must have $r_t^a \geq r_t^d$). In other words, higher monitoring activity worsens the agency problem between a bank and a depositor. To overcome this moral hazard and attract more deposits, an increasing share of the investment project should be financed by the 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 to attract outside funding.

2.3.3 Monitoring at the Project Level

Given the competitively behaving banking sector, the optimimal choice of c_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 (19) as $p_H b\left(c_t\right) n_t / \left[g\left(r_t^a, r_t^d, q_t, c_t\right)\Delta p\right]$. Therefore the optimal level of monitoring solves the problem

$$\max_{c_t \geq 0} \frac{b\left(c_t\right)}{g\left(r_t^a, r_t^d, q_t, c_t\right)}. \tag{21}$$

As can be seen from equations (20) and (21) the effects of monitoring on the entrepreneur's expected payoff are complex. The denominator in the problem (21) shows how 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 (the second term in $g(\cdot)$ in equation (20)). However, smaller agency problems enable larger leverage (the first term in $g(\cdot)$ in equation (20)). This provides an incentive for monitoring.

To derive a tractable analytic solution to the problem (21), we specify the following functional form for $b(c_t)$:

$$b(c_t) = \begin{cases} \Gamma c_t^{-\frac{\gamma}{1-\gamma}} & \text{if } c_t > \underline{c} \\ \bar{b} & \text{if } c_t \leq \underline{c} \end{cases}, \tag{22}$$

where $\Gamma > 0$, $\bar{b} > 0$, $\gamma \in (0,1)$, and $\underline{c} \geq 1$. The first row of equation (22) shows how $b(c_t)$ is differentiable and strictly convex for $c_t > \underline{c}$ and that the monitoring technology is the more efficient the larger is γ or the smaller is Γ. 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 smaller rate of return than a good project even for low levels of c_t.[8]

Under the minimum scale requirement, the entrepreneur may choose a corner solution with no monitoring $c_t = 0$, $b(c_t) = \bar{b}$, or a unique interior solution $c_t = c_t^*$. In the appendix we determine the conditions under which we can rule out the corner solution. These conditions are met around the steady state in which we focus on in this paper. After substitution of equations (20) and (22) we can write the unique interior solution to the entrepreneur's problem (21) as

$$c_t^* = \frac{\gamma \rho_t}{1 + \frac{p_H}{\Delta p}\left(1 - \frac{1+r_t^d}{1+r_t^a}\right)}. \tag{23}$$

The optimal level of monitoring intensity characterized by equation (23) has intuitive properties: It is increasing in the elasticity of monitoring technology (directly related to γ) and in the rate of return on the good project (ρ_t). Also, the larger the negative effects of monitoring on leverage (which are in the denominator), the smaller the optimal level of monitoring.

[8]Naturally, we have experimented with many other functional forms besides specification (22) without obtaining additional insights or simpler expressions.

2.4 Aggregation

We proceed under the assumption that all projects will be monitored with the same intensity given by equation (23) 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 the project level to the economy-wide level in terms of capital structures is simple. Clearly,

$$\frac{a_t}{i_t} = \frac{A_t}{I_t}, \ \frac{d_t}{i_t} = \frac{D_t}{I_t}, \text{ and } \frac{n_t}{i_t} = \frac{N_t}{I_t}. \tag{24}$$

where capital letters stand for aggregate level variables.

The economy-wide equivalent to monitoring intensity can be found by combining (24) with the banker's incentive and participation constraints (10) and (12). This gives

$$c_t^* = \frac{\Delta p}{p_H} \frac{1 + r_t^a}{1 + r_t^d} \frac{A_t}{I_t}. \tag{25}$$

Since in equilibrium the monitoring intensity given by equation (25) must be equal to the one in equation (23), we have

$$1 + r_t^{a*} = \left(1 + r_t^d\right) \frac{\left(1 + \gamma \rho_t \frac{I_t}{A_t}\right)}{1 + \frac{\Delta p}{p_H}}. \tag{26}$$

For equation (26) to characterize the equilibrium rate of return on bank capital, it must hold that

$$r_t^{a*} > r_t^d. \tag{27}$$

Otherwise, $r_t^{a*} = r_t^d$. We proceed under the assumption that inequality (27) holds, verifying that the assumption is fulfilled in equilibrium later.

Next, we determine aggregate investment and leverage. Equations (13) and (24) imply

$$\frac{D_t}{I_t} = 1 + c_t^* - \frac{A_t + N_t}{I_t}. \tag{28}$$

Substituting equations (22), (24), (25), (26), and (28) for equation (18) yields after some algebra

$$\left(\frac{A_t}{I_t^*}+\gamma\rho_t\right)^{\gamma}\left(\frac{N_t}{I_t^*}+(1-\gamma)\,\rho_t\right)^{1-\gamma}=\left(\frac{\Gamma}{\left(1+r_t^d\right)}\frac{p_H}{\Delta p}\right)^{1-\gamma}\left(1+\frac{p_H}{\Delta p}\right)^{\gamma} \tag{29}$$

Equation (29) implicitly determines the aggregate investment level I_t^* in the economy.

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

$$Y_t = C_t + I_t. \tag{30}$$

Note from equation (30) 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 λ^e and λ^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

$$A_{t+1} = \left[r_{t+1}^K + q_{t+1}\,(1-\delta)\right]\lambda^b p_H R_t^b I_t, \tag{31}$$

which may be combined with conditions (12) and (24) to get the following law of motion for the aggregate bank capital:

$$A_{t+1} = \frac{A_t \lambda^b \left(1 + r_t^a\right) \left[r_{t+1}^K + (1-\delta)\, q_{t+1}\right]}{q_t}. \tag{32}$$

Similarly, the aggregate entrepreneurial capital is given by

$$N_{t+1} = \left[r_{t+1}^K + q_{t+1}(1-\delta)\right] \lambda^e p_H R_t^e I_t, \tag{33}$$

which we can rewrite as

$$N_{t+1} = \frac{N_t \lambda^e \left(1 + r_t^e\right) \left[r_{t+1}^K + (1-\delta)\, q_{t+1}\right]}{q_t} \tag{34}$$

where

$$1 + r_t^e \equiv q_t p_H R_t^e I_t / N_t \tag{35}$$

denotes the rate of return on entrepreneurial capital. Equation (34) gives the law of motion for aggregate entrepreneurial capital.

2.5 Equilibrium

Since in our model deposits occur within a period, they carry no interest rate, i.e., $r_t^{d*} = 0$ [9]. In addition to $r_t^{d*} = 0$, an equilibrium of the economy is a time path

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

that satisfies equations (3), (4), (5), (6), (7), (8), (25), (28), (29), (30), (32), (34) In what follows, we study a dynamic equilibrium in the neighborhood of a non-stochastic steady state of the model.

[9] We plan to relax the assumption of intra-period deposits in future work.

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 ν_t, (denoted by ν, i.e., $\lim_{t\to\infty} \nu_t = \nu$.)

Proposition 1 *If $\beta > \max\left\{\lambda^e, \lambda^b\right\}$, there exists a steady state satisfying condition* (27) *where the ratio of informed capital* (ν) *is given by*

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

Proof. In the Appendix A.1 ■

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 smaller than the household's rate for time preference. Intuitively the household must be sufficiently patient to let its bankers and entrepreneurs retain their earnings.

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

Proposition 2 *i) The ratio of informed capital maximizing output* (ν^{**}) *is given by*

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

Proof. In the Appendix A.2 ■

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 problem are effectively alleviated, more funds for entrepreneurs' investments can be raised from depositors. But to ensure that bankers have incentives to monitor intensively, a large (enough) banker stake (i.e., a high ratio $\nu^{**} = A/N$) is called for.

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 $\nu^{**} \gtreqqless \nu$ *if*

$$\frac{\lambda^b}{\lambda^e} \lesseqqgtr 1 + \frac{\Delta p}{p_H}.$$

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 the scarcity of entrepreneurial capital: Only if the bankers' survival probability is larger than the entrepreneurs' survival probability by a factor that is strictly larger than one, the bankers may accumulate more capital than what is needed to maximize investments and output in the economy.

Proposition 3 has an important implication: Differentiating equation (29) around the steady state yields (see the Appendix for details)

$$\left.\frac{dN}{dA}\right|_{I^*} = -\frac{1 + \frac{\Delta p}{p_H} - \frac{\lambda^b}{\beta}}{\left(1 + \frac{\Delta p}{p_H}\right)\left(1 - \frac{\lambda^e}{\beta}\right)}. \tag{36}$$

If we view $I_t^*(A_t, N_t)$ as given by equation (29) as the economy's production technology, $dN/dA|_{I^*}$ defines the marginal rate of technical subtitution of bank and entrepreneurial capital. It is immediate that

$$\left.\frac{dN}{dA}\right|_{I^*} \lesseqqgtr -1$$

if

$$\frac{\lambda^b}{\lambda^e} \lesseqgtr 1 + \frac{\Delta p}{p_H}.$$

In words, if bank capital is scarce, the (absolute) value of marginal rate of technical subsitution is above one and, as a result, increasing bank capital boosts the aggregate investments more than 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 (31) by equation (33) 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 to 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, $p_H q_t \left(R_t - R_t^b - R_t^e\right)$, (i.e., the highest revenue share that can be pledged to depositors without jeopardizing entrepreneurs' and bankers' incentives), minus the cost of monitoring, c_t. But there is a tradeoff: 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:

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

subject to equations (9), (10), (22), and $r_t^{d*} = 0$. The first-order condition for this problem may be written as

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

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

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

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 assuming that in some period t project success probabilities are given by

$$\widetilde{p}_{\tau t} = p_\tau(1+\varepsilon_t),\ \ \tau \in \{H, L\}\,, \tag{37}$$

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

We assume that the shock realized after financing contracts have been signed, monitoring and project choices made, and price of capital goods determined. Futhermore, neither pricing of capital goods nor financial contracts cannot be made contingent on the realization of the shock. While in theory it would be possible to contract on aggregate investment level, in practice such contracts are rare. In essence, we are assuming capital goods are sold via forward contracts where 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 of period t.[10]

To model the effects of an aggregate shock, we make a 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 successfull 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 which 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 and successful bankers then share what is left at the bank.

For brevity, we assume that event 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 the 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.[11]

Following an investment shock in period t, the aggregate entrepreneurial

[10] 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.

[11] 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. $q_t p_L \left(R - R_t^e\right) < d_t / i_t$). Hence, depositors are only willing put their money into a bank, if they know that the bankers have high enough own stakes, and proper incentives to monitor.

capital in period $t+1$ is given by

$$N_{t+1}(\varepsilon_t) = N_t \left[r_{t+1}^K + q_{t+1}(1-\delta)\right] \lambda^e I_t (1+r_t^e) p_H (1+\varepsilon_t). \qquad (38)$$

This directly follows from equations (33) and (37). Clearly the ratio of $N_{t+1}(\varepsilon_t)$ to N_{t+1} of equation (33) 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

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

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

Using conditions (11) (recalling that $r_t^{d*}=0$), (12), (14), and (24) the evolution of the aggregate bank capital maybe re-expressed as

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

Now dividing $A_{t+1}(\varepsilon_t)$ of equation (39) by A_{t+1} of equation (32) 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 the 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 fewer bankers see their projects succeed but also each successful bankers 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 the investment project fails, the firm goes bankrupt and the entrepreneur loses his equity; however 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 the 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 (37) 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 Calibration

In calibrating the real sector of the model, we can follow the literature. Period is one year. The household utility function parameters are calibrated to imply relatively modest risk aversion and fairly inelastic labour supply, so $\sigma = 2$, $\phi = 0.5$, and $\xi = 2$. The discount factor β is calibrated to 0.98, which approximately corresponds an annual real interest rate of 2%. The depreciation rate δ is set to 0.0963, which is a typical value in the business cycle literature, and results in the 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), α, is set to 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 autogressive 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 that of the standard RBC model. The output shares of the investments and consumption are roughly 20% and 80%, respectively.

The 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 D.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 the estimates from 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 to 0.14 which lies in the mid-range of these estimates.

To parameterize the steady-state (excess) rate of return on entrepreneurial capital, r^e, we first take the value of 6.5% for 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 intemporal 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 the banks' assets since that gives us the amount of funds that the banks allocate in the investment projects. As a result the bank's steady-state capital ratio of our interest is given by $A/(A + D - cI) = A/(I - N)$. 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 that contains 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 while 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 upperbound 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 the monitoring cost to asset ratio $(cI/(I - N))$ to be 1.5%.

6 Impulse Responses

Figures 1 and 2 show the impulse responses of key real and financial sector variables to a positive technology and a negative investment shock, respectively. 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 1 indicate that the first-round effects of the

Table 1: Calibrated parameter values

Parameter	Value	Note
		Parameters of the macro block
β	0.9804	discount factor
α	0.33	capital share
δ	0.0963	rate of decay of capital
ξ	2	parameter of the disutility of labor
ϕ	0.5	$1/\phi$ Frish elasticity of labor supply
ρ	0.65	persistence of technology shock
σ_ε	0.006	standard deviation of the technology shock innovation
σ	2	$1/\sigma$ elasticity of intertemporal substitution
		Parameters of the financial block
λ^e	0.9382	survival rate of entrepreneurs
λ^b	0.8600	survival rate of bankers
γ	0.4158	$\gamma/(1-\gamma)$ elasticity of monitoring function
Γ	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: Impulse responses to a positive technology shock (1 % increase in Z_t)

Figure 2: Impulse responses to a negative investment shock (1 percentage point decrease in success probabilities)

technolocy shock on investments and working hours are dampened because 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 technolocy 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 that would smooth the consumption and investment effects of the technology shock.

More interestingly, Figure 2 shows that financial intermediation amplifies the investment shock on aggregate investments 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 senority 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 become smaller, entrepreneurs need to be given a larger share of the 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 an equal (proportional) change in entrepreneurial wealth.

In sum, because an investment shock has a stronger effect on bank capital than on entrepreneural wealth and because changes in bank capital matter more for the aggregate investments 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 then also translates into a sizeable effect on real output, employment and other macro variables.

7 Public policies

In this section we analyze two possible policy measures the government can undertake. First, the government can strengthen the balance sheets of banks, by injecting new government-owned equity. Second, the government can directly fund the non-financial firms. From the social point of view, both of these policies involve both 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 lower investments.

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

7.1 Social costs of public funding: incentives

Let us assume that the government injects an aggregate amount $A_t^g \geq 0$ of equity capital to the banking system and funds entrepreneurial firms by an aggregate amount $N_t^g \geq 0$. As we shall discuss below (see the end of Section 7.2), the public funding to non-financial firms can be thought of as either equity injections or as loans. We assume that the government does not (have the technology to) monitor the entrepreneurs: the publicly funded firms also get loans from banks, and the bankers conduct the monitoring. The government demands an expected rate of return $(1 + r_t^{ga})$ for its investments in the banking sector, and an expected rate of return $(1 + r_t^{ge})$ for its investments in the non-financial sector. One way to interpret the conditions of public funding is that the government buys bank equity at (unit) price $Q_t^a = (1+r_t^a)/(1+r_t^{ga})$ and firm equity at (unit) price $Q_t^e = (1 + r_t^e)/(1 + r_t^{ge})$. We assume that

$r_t^{ga} > r_t^d$ and $r_t^{ge} > r_t^d$: the governments 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 the banks and the firms would want to be funded by the government. Finally, participation to these governments programs is mandatory for all banks and/or firms, with an individual bank receiving $a_t^g = a_t \left(A_t^g / A_t\right)$ of government-owned capital, and an individual firm getting $n_t \left(N_t^g / N_t\right)$ of public funds.

We first study the social costs of government policies: public funding distorts incentives and results in lower investments. Let us further elaborate the argument. Since the government has to paid its share of the revenues from the investment projects, less money can be credibly pledged to outside investors, without violating bankers' and entrepreneurs' incentive constraints. But then fewer funds can be raised from outside investors. In other words, public funds crowd out the funds provided by outside investors. Furthermore, since the government demands a premium ($r_t^{ga} > r_t^d, r_t^{ge} > r_t^d$), this crowding out is more than one-to-one, i.e. each dollar of government money crowds out more than one dollar private money.

To view the situation from a slightly different angle, government funding dilutes the insiders' (bankers' and entrepreneurs') stakes in the investment projects, and this then leads to a lower investment scale. In the appendix we show that the equation characterizing aggregate investments (29) is modified as follows

$$\left(\frac{A_t - \left(\frac{r_t^{ga} - r_t^d}{1 + r_t^d}\right) A^g}{I_t^*} + \gamma \rho_t\right)^{\gamma} \left(\frac{N_t - \left(\frac{r_t^{ga} - r_t^d}{1 + r_t^d}\right) N^g}{I_t^*} + (1 - \gamma)\,\rho_t\right)^{1-\gamma}$$

$$= \left(\frac{p_H}{\Delta p} \frac{\Gamma}{\left(1 + r_t^d\right)}\right)^{1-\gamma} \left(1 + \frac{p_H}{\Delta p}\right)^{\gamma} \qquad (40)$$

Bank capitalization essentially dilutes bankers' stakes by $\left(\frac{r_t^{ga} - r_t^d}{1 + r_t^d}\right) A^g$, while public funding in entrepreneurial firms dilutes entrepreneurs' stakes by $\left(\frac{r_t^{ge} - r_t^d}{1 + r_t^d}\right) N^g$.

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

$$1 + r_t^a = \frac{1 + \gamma\rho_t \frac{I_t}{A_t} - r_t^{ga} \frac{A_t^g}{A_t}}{1 + \frac{\Delta p}{p_H}} \tag{41}$$

$$1 + r_t^e = 1 + (1 - \gamma)\,\rho_t \frac{I_t}{N_t} - r_t^{ge} \frac{N_t^g}{N_t} \tag{42}$$

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

7.2 Social benefits of public funding: stability

Next we move to 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 the macro economy. In the appendix 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

$$A_{t+1}(\varepsilon_t) = A_t \lambda^b \left(\frac{r_{t+1}^K + (1 - \delta)\, q_{t+1}}{q_t} \right) \left[(1 + \varepsilon_t)(1 + r_t^a) + \varepsilon_t \frac{D_t(A_t^g, N_t^g)}{A_t + A_t^g / Q_t} \right]. \tag{43}$$

Comparing equations (39) and (43) shows how public funds in banks and/or non-financial firms lower the bank leverage accelerator of shocks from D_t/A_t to

$$BL_t = \frac{D_t(A_t^g, N_t^g)}{A_t + A_t^g / Q_t^a}, \tag{44}$$

where the aggregate household deposits are now (see the appendix for the derivation) given by

$$D_t(A_t^g, N_t^g) = (1 + c_t(A_t^g, N_t^g))\, I_t(A_t^g, N_t^g) - (N_t + A_t + A_t^g + N_t^g), \tag{45}$$

instead of $D_t = D_t(0,0)$, as given by equation (28).

Note that besides the direct negative impact, bank capitalization A_t^g has an indirect negative impact on $D_t(A_t^g, N_t^g)$, since the term $(1 + c_t(A_t^g, N_t^g))\, I_t\,(A_t^g, N_t^g)$ is decreasing in A_t^g .[12] As a result, equation (44) suggests that bank leverage is lowered both because the total bank equity is enhanced thanks to equity A_t^g/Q_t^a purchased by the government (the denominator of (44)) and because government capital A_t^g crowds out debt funding from households (the numerator of (44)). 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 (the numerator of (44)); quite naturally direct funding to non-financial firms does not strengthen the equity buffer of the banking system.

Above we have studied how public policies lower the bank leverage accelerator of shocks. On the firm side, there is no leverage accelerator of shocks that could be possibly dampened: despite public funding, the dynamics of entrepreneurial capital are still given by equation (**??**); the only difference is that $(1 + r_t^e)$ is now characterized by (42). Essentially, the bankruptcy, and limited liability, of individual firms in case of project failure protects other firms from negative spill-overs. But bankruptcy and limited liability also protect government investments in the non-financial sector: government money invested into 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.

[12] In Section 7.1 we show how $I_t\,(A_t^g, N_t^g)$ is decreasing A_t^g. It is also fairly straightforward to show that the term $(1 + c_t(A_t^g, N_t^g))\, I_t\,(A_t^g, N_t^g)$ is decreasing in A_t^g.

7.3 Funding banks or funding firms: cost-benefit analysis

Now we come the main policy question of the paper. The government has decided to use a certain sum M to provide funding for banks and non-financial firms . How should these resources be allocated between banks (A^g) and firms (N^g)?

To get sharp analytical results, we adopt some further assumptions. First, we assume that the excess return that the government demands from banks and firms is (very) small

$$r_t^{ga} - r_t^d = r_t^{ge} - r_t^d = dr_t$$

(where dr_t is very small). This assumption can be motivated by the fact that larger premia would further distort incentives - see Section 7.1. Since the investment shock (ε_t) is also assumed to be small, we can essentially 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[13], the bankers, the entrepreneurs as well as the workers, for any *direct* costs due to capital injections. To be more specific, at the beginning of period $t+1$ the government pays $S^e = N^g dr_t$ to the entrepreneurs, $S^a = \left(1 + \frac{\Delta p}{p_H}\right)^{-1} A^g dr_t$ to the bankers and $S^w = \frac{\Delta p}{p_H}\left(1 + \frac{\Delta p}{p_H}\right)^{-1} A^g dr_t$ to the workers.[14] 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 (41) and (42) above - while

[13]The compensation received by an individual banker or entrepreneur does not depend on his or her actions.

[14]In the appedix 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 $A^g dr_t - \left(1 + \frac{\Delta p}{p_H}\right)^{-1} A^g dr_t = \left(1 + \frac{\Delta p}{p_H}\right)^{-1} A^g dr_t$. Also remember that in our framework the banks pay the monitoring costs to workers; hence workers lose $\frac{\Delta p}{p_H}\left(1 + \frac{\Delta p}{p_H}\right)^{-1} A^g dr_t$.

still 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 the insiders' (bankers' and/or entrepreneurs') stakes and thereby lowers, and distorts, aggregate investments. These observations 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*, both in the present period and in all future periods. In particular, we obtain the relative impact of these policies on utility (both in the present period and in future periods). As a result, we can derive a utility-based benefit ratio of the two policy options (how much does bank capitalization dampen the effects of a negative investment shock, relative to firm capitalization) as well as a utility-based cost ratio of the policies (how much does bank capitalization distort the economy, compared to firm capitalization). Finally, we can derive a utility-based ratio of the benefit ratio and the cost ratio; this statistic essentially tells which policy option has the better (utility-based) cost-benefit ratio (typically, it's bank capitalization).

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

$$\overline{BL}\left(A^g, N^g\right) = \frac{(1+\overline{c})\,\overline{I} - \left(\overline{A} + \overline{N} + A^g + N^g\right)}{\overline{A} + A^g/\overline{Q}} = \frac{\overline{D} - A^g - N^g}{\overline{A} + A^g/\overline{Q}}$$

where $\overline{D} = (1+\overline{c})\,\overline{I} - \left(\overline{A} + \overline{N}\right)$ is steady state deposits, in the absence of government policies.[15] The benefits of capitalization derive from lower leverage: less levered banks are more resilient in the face of a negative investment shock. Then the *benefit ratio* of injecting the marginal euro or dollar into

[15] Remember, that up to a first-order approximation we can here ignore the effect of public policies on c_t and I_t; these cross effects are proportional to $dr_t * \varepsilon_t$.

the banks rather than into the firms is given by

$$
\begin{aligned}
BR(A^g, N^g) &= \frac{\partial \overline{BL}(A^g, N^g)/\partial A^g}{\partial \overline{BL}(A^g, N^g)/\partial N^g} = \frac{1 + \left(\overline{D} - N^g\right)/\left(\overline{QA}\right)}{1 + A^g/\left(\overline{QA}\right)} \qquad (46) \\
&= 1 + \frac{\left(\overline{D} - M\right)/\left(\overline{QA}\right)}{1 + A^g/\left(\overline{QA}\right)}
\end{aligned}
$$

Clearly (since $BR > 1$ as long as $M < \overline{D}$) injecting capital into banks is a more effective way to bring leverage down than funding firms: a capital injection into banks strengthens the shock cushion of banks, while 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 (M) is relatively small. This is natural, since 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 ($\frac{M}{A}$ is close to zero, and as a consequence also $A^g/\overline{A}$ and $N^g/\overline{A}$ are close to zero) gives a benefit ratio $BR \approx \left(1 + \frac{\overline{D}}{\overline{QA}}\right) = 11.3$. However, the benefit ratio becomes smaller, when the size of capital injections grows. For example, taking our baseline calibration and assuming for simplicity that the government targets only banks ($A^g = M$ and $N^g = 0$) gives $BR = 6.0$, when $\frac{M}{A} = 1$ and $BR = 4.1$ when $\frac{M}{A} = 2$. This is also quite intuitive: when banks have more equity (banker-owned or government-owned) in their balance sheets, any additional unit capital has a smaller proportional effect on the shock cushions.

Next we turn to studying the social costs of public funding. From (40) we can 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 fall in investments represents a distortion. Then, the *cost ratio* of allocating the marginal euro or dollar of government money into banks, as opposed to non-financial firms, is given by

$$CR = \frac{\left(-\frac{dI_t}{dA_t}dr_t\right)}{\left(-\frac{dI_t}{dN_t}dr_t\right)} = \left|\frac{dN}{dA}\right|_{|I^*} = \frac{1-\frac{\lambda^b}{\beta}+\frac{\Delta p}{p_H}}{\left(1+\frac{\Delta p}{p_H}\right)\left(1-\frac{\lambda^e}{\beta}\right)} \tag{47}$$

where the steady state marginal rate of technical substitution $\frac{dN}{dA}_{I^*}$ was derived in Section 3.[16]

The distortions arise because government ownership in either banks or non-financial firms dilutes the insiders' (bankers' and entrepreneurs') stakes and blunts their incentives. 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 the bankers' stakes proportionally more than capital injections into firms dilutes the entrepreneurs' stakes. This observation is also reflected in the relative costs of the 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 and funding 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, the important thing for the government, or the society, is not benefits or costs as such, but the trade-off between costs and benefits. To study this issue, we next compute the ratio of the benefit ratio (BR) and the cost ratio (CR)

$$BCR = \frac{BR}{CR} = \left(\frac{1+\left(\overline{D}-N^g\right)/\left(\overline{QA}\right)}{1+A^g/\left(\overline{QA}\right)}\right)\left|\frac{dA}{dN}\right|_{|I^*}$$

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

If $BCR > 1$ the government faces a better trade-off between costs and benefits, when targeting banks rather than when targeting firms. In other

[16] Remember that the marginal rate of technical substitution is defined by the equation $\frac{dI_t}{dA_t}dA_t + \frac{dI_t}{dN_t}dN_t = 0 \Leftrightarrow \frac{dN_t}{dA_t} = -\frac{dI_t}{dA_t}/\frac{dI_t}{dN_t}$.

words, no matter what relative weights the government, or the society, assigns on the benefits (less levered banks, which are more resilient in the face of investment shocks) and the costs (lower lending and less investment, if there are no adverse shocks) of capital injections, the government should invest the marginal euro or dollar into the banks.[17] If $BCR < 1$, we have the opposite situation, and the government should allocate the marginal euro or dollar into the non-financial firms. Finally, if $BCR = 1$, both options are equally good (or bad) ways to invest the marginal euro or dollar.

Next we state the main policy result of the paper, the so called "pecking order" of public funding:

Proposition 4

Let

$$\widehat{M}_1 = \left|\frac{dA}{dN}\right|_{|I^*} \left(1 + \frac{\overline{D}}{\overline{QA}} - \left|\frac{dN}{dA}\right|_{|I^*}\right) \overline{QA}$$

and

$$\widehat{M}_2 = \left(1 + \frac{\overline{D}}{\overline{QA}} - \left|\frac{dN}{dA}\right|_{|I^*}\right) \overline{QA}$$

where $\widehat{M}_2 > \widehat{M}_1 > 0$, if $\left|\frac{dN}{dA}\right|_{|I^*} > 1$ and $1 + \frac{\overline{D}}{\overline{QA}} - \left|\frac{dN}{dA}\right|_{|I^*} > 0$.

a) If $M \geq \widehat{M}_1$ the government should target only banks:

$$A^g = G, \; N^g = 0$$

b) If t $M \in \left(\widehat{M}_1, \widehat{M}_2\right)$, the government should target both banks and non-financial firms.

$$A^g = \left(\frac{\widehat{M}_2 - M}{\widehat{M}_2 - \widehat{M}_1}\right) \widehat{M}_1, \tag{48}$$

$$N^g = \left(\frac{M - \widehat{M}_1}{\widehat{M}_2 - \widehat{M}_1}\right) \widehat{M}_2 \tag{49}$$

[17]-The relative weights the government assigns on the benefits and the costs can depend for example on the (perceived) probability and the (perceived) size of adverse investment shocks.

c) If $M \geq \widehat{M_2}$, the government should target only non-financial firms

$$A^g = 0, \;\; N^g = G$$

Proof. See the appendix. ■

Next we provide some discussion and interpretation; see also Figure 3 for illustration. Proposition 4 essentially describes a pecking order of public funding: As stated in item a), the government should only target banks, if the size of the public funding is small or moderate. Non-financial firms should be targeted, along-side with banks, only if the size of public funding exceeds a certain limit $\widehat{M_1}$. Typically, the critical value $\widehat{M_1}$ of policy measures, given in Proposition 4, is relatively large. For example, with our baseline calibration $\frac{\widehat{M_1}}{A} = 1.1$. In this case, Proposition 3 indicates that the government should target only banks, unless the size of capital injections exceeds banker-owned equity. To sum up the gist of the argument: with small and moderate sized capitalizations, the benefit calculus, favoring banks, clearly trumps the cost calculus, favoring firms.

If the total amount of public funding is larger $M \in \left(\widehat{M_1}, \widehat{M_2}\right)$, 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 M, by more than one-to-one, while the sum of money (A^g) allocated to banks should be actually *decreasing* in M. This latter finding may seem somewhat surprising. To understand the intuition behind the result, first remember that the relative benefits of targeting banks decrease, when the size of capital injections grow (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 trumps [overshadows] the cost calculus, but 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 into 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 deposit - and lower leverage in turn implies that a larger shock cushion is of less value (see the first form of expression (46): $\frac{\partial BR}{\partial N^g} < 0$, when A^g is fixed). These two observations then explain the result stated in item b): When a certain limit $\widehat{M}_1$ 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 into 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, $M \geq \widehat{M}_2$. 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 $\widehat{M}_2$ is typically very high. For example, with our baseline calibration $\frac{\widehat{M}_2}{A} = 6.3$; 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.

8 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 investments 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 dynamics, than 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 offers 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 becomes smaller when banks have more equity - banker-owned or government-owned - in their balance sheets.

References

Acharya, Viral and Sascha Steffen (2014) Falling Short of Expectations? Stress-Testing the European Banking System. Unpublished manuscript. NYU Stern, January 15, 2014.

Aikman, David and Matthias Paustian (2006): Bank Capital, Asset Prices, and Monetary Policy, Bank of England Working Paper no. 305.

Albertazzi, Ugo and Leonardo Gambacorta (2009): Bank profitability and the business cycle, *Journal of Financial Stability*, 5, 393–409.

Alessandri, Piergiorgio and Andrew G Haldane (2009): *Banking on the State*, unpublished note, Bank of England.

Altinkilic, Oya and Robert S. Hansen (2000): Are there Economies of Scale in Underwriting Fees? Evidence of Rising External Financing Costs, *The Review of Financial Studies*, Vol. 13, No. 1, pp- 191–218.

Berger, Allen N. and Bouwman, Christa H. S. and Kick, Thomas K. and Schaeck, Klaus (2014): *Bank Risk Taking and Liquidity Creation Following Regulatory Interventions and Capital Support*, http://dx.doi.org/10.2139/ssrn.1908102

Berger, Allen N. and Raluca A. Roman (2015): *Did Saving Wall Street Really Save Main Street? The Real Effects of TARP on Local Economic Conditions.* Mimeo

Bernanke, Ben, Gertler, Mark and Simon Gilchrist (1999): The financial accelerator in a quantitative business cycle framework, in Taylor, J. and Woodfords M. (eds.), *Handbook of Macroeconomics*, Elsevier Science, Amsterdam.

Carlstrom, Charles T. and Timothy S. Fuerst (1997): Agency Costs, Net Worth, and Business Fluctuations: A Computable General Equilibrium Analysis, *American Economic Review*, 87, 893–910.

Castrén, Olli and Tuomas Takalo (2000): Captial Market Development, Corporate Governance, and the Credibility of Currency Pegs, European Central Bank Working Paper no. 34.

Chen, Nan-Kuang (2001): Bank Net Worth, Asset Prices, and Economic Activity, *Journal of Monetary Economics*, 48, 415–436.

Christensen, Ian, Meh, Cesaire A. and Kevin Moran (2011): Bank Leverage Regulation and Macroeconomic Dynamics, Unpublished manuscript, Bank of Canada & Université Laval.

De Jong, Abe, Kabir, Rezaul and Thuy Thu Nguyen (2008): Capital structure around the world: The roles of firm- and country-specific determinants, *Journal of Banking & Finance*, Vol. 32, Issue 9, 1954–1969

Duchin, Ran and Denis Sosyura (2014): Safer ratios, riskier portfolios: Banks? response to government aid,*Journal of Financial Economics*, Volume 113, Issue 1, Pages 1–28.

European Commission (2014): State Aid Scoreboard 2013, Aid in the context of the financial and economic crisis. `http://ec.europa.eu/competition/state_aid/scoreboard/financial_economic_crisis_aid_en.html`, March 2014.

Faia, Ester (2010): Credit Risk Transfers and the Macroeconomy, Unpublished manuscript, Goethe University.

Gertler, Mark and Peter Karadi (2010): A Model of Unconventional Monetary Policy, *Journal of Monetary Economics*, 58, 17–34.

Gertler, Mark and Nobuhiro Kiyotaki (2011): Financial Intermediation and Credit Policy in Business Cycle Analysis, *Handbook of Monetary Economics*

Giannetti, Mariassunta, and Andrei Simonov (2013) On the Real Effects of Bank Bailouts: Micro Evidence from Japan. *American Economic Journal: Macroeconomics*, 5(1): 135–67.

Graham, John R. and Mark T. Leary (2011): A Review of Empirical Capital Structure Research and Directions for the Future, *Annual Review of Financial Economics*, Vol. 3.

Graham, John R., Leary , Mark T. and Michael R. Roberts (2014): A Century of Capital Structure: The Leveraging of Corporate America, forthcoming in *Journal of Financial Economics*

Haldane, Andrew and Piergiorgio Alessandri (2009), *Banking on the State*, presentation delivered at the Federal Reserve Bank of Chicago twelfth annual International Banking Conference on “The International Financial Crisis: Have the Rules of Finance Changed?”, Chicago, 25 September 2009.

Holmstrom, Bengt and Jean Tirole (1997): Financial Intermediation, Loan-able Funds, and the Real Sector, *Quartely Journal of Economics* 112, 663–691.

Hoshi, Takeo and Anil K. Kashyap (2010): Will the U.S. Bank Recapitalization Succeed? Eight Lessons from Japan, *Journal of Financial Economics*, 97, 398–417.

Kiyotaki,Nobuhiro and John Moore (1997): Credit cycles, *Journal of Political Economy* 105,211–248.

Laeven, Luc and Fabian Valencia (2012): *Systemic Banking Crises Database: An Update*, IMF Working Paper, WP/12/163.

Li, Lei (2013): TARP funds distribution and bank loan supply, *Journal of Banking & Finance*, Volume 37, Issue 12, 4777–4792.

Lin, Da (2013): Bank Recapitalizations: A Comparative Perspective, *Harvard Journal on Legislation*, 50, 513–544.

Labonte, Marc (2016): *Federal Reserve: Emergency Lending*, Congressional Research Service, 7-5700.

Meh, Cesaire A. and Kevin Moran (2010): The Role of Bank Capital in the Propagation of Shocks, *Journal of Economic Dynamics & Control*, 34, 555–576

Philippon, Thomas (2013): *Has the U.S. Finance Industry Become Less Efficient? On the Theory and Measurement of Financial Intermediation*, Working Paper, December 2013. `http://pages.stern.nyu.edu/~tphilipp/papers/Finance_Efficiency.pdf`

Puddu, Stefano and Andreas Wälchli (2013): *TARP Effect on Bank Lending Behaviour: Evidence from the last Financial Crisis.*

Rajan, Raghuram G and Luigi Zingales (1995): What Do We Know about Capital Structure? Some Evidence from International Data, *The Journal of Finance*, 50, 1421–1460.

A Appendix

A.1 Proof of Proposition 1

Proof. Substitution of the incentive constraints (9) and (10), together with equation (22) and $r^{d*} = 0$ for equations (31) and (33) gives

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

and

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

Thus, in a steady state we must have

$$A = \left(\frac{r^K}{q} + 1 - \delta\right) \frac{p_H}{\Delta p} \lambda^b c I \tag{50}$$

and

$$N = \left(\frac{r^K}{q} + 1 - \delta\right) \frac{p_H}{\Delta p} \lambda^e \Gamma c^{-\frac{\gamma}{1-\gamma}} I. \tag{51}$$

Here and in what follows we denote a steady state of some time-depenent variable X_t by X, i.e., $\lim_{t \longrightarrow \infty} X_t = X$. Dividing equation (50) by equation (51) implies that

$$\nu \equiv \frac{A}{N} = \frac{\lambda^b}{\lambda^e} \frac{c^{\frac{1}{1-\gamma}}}{\Gamma}. \tag{52}$$

Next, substitution of equation (26) for equation (23) yields after some algebra the steady state value of c as

$$c = \frac{\gamma\rho + \frac{A}{I}}{1 + \frac{p_H}{\Delta p}}. \tag{53}$$

Equation (29) can be rewritten at a steady state as

$$\frac{\gamma\rho + \frac{A}{I}}{1 + \frac{p_H}{\Delta p}} = \left[\frac{\frac{p_H}{\Delta p}\Gamma}{(1-\gamma)\rho + \frac{N}{I}}\right]^{\frac{1-\gamma}{\gamma}}. \tag{54}$$

Combining equations (53) and (54) and solving for ρ yields

$$\rho = \frac{1}{1-\gamma}\left(\frac{p_H}{\Delta p}\Gamma c^{-\frac{\gamma}{1-\gamma}} - \frac{N}{I}\right). \tag{55}$$

Inserting equation (55) into (53) gives

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

After substituting equations (50) and (51) for the above formula we obtain

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

By using the definition ν from equation (52), this may 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 ν from the above equation gives

$$\nu = \left(\frac{\gamma}{1-\gamma}\right)\left[\frac{\frac{1}{\lambda^e} - \frac{r^K}{q} - 1 + \delta}{\frac{1}{\lambda^b}\left(1+\frac{\Delta p}{p_H}\right) - \frac{r^K}{q} - 1 + \delta}\right]. \tag{56}$$

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

$$\beta = \frac{q}{r^K + (1-\delta)\,q}. \tag{57}$$

Using equation (57), equation (56) 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 condition

$$\beta > \max\left\{\lambda^e, \lambda^b\right\}. \tag{58}$$

holds. Clearly, if $\lambda^b > \lambda^e$, condition (58) is a sufficient condition. Furthermore if condition (58) holds, equation (32) implies that in a steady state we must have $r^{a*} > 0$, i.e., condition (27) is satisfied. ■

A.2 Proof of Proposition 2

Proof. We seek the value of ν_t that maximizes the aggeregate leverage $1/G_t = I_t/(A_t + N_t)$ and by implication, aggregate investments and output for a given level of aggregate informed capital $A_t + N_t$. By 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 (29) — 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 ν_t gives

$$\left.\frac{dG_t^*}{dv_t}\right|_{I_t^*} = \frac{G_t^* \left\{1 - \gamma - \left(\frac{\nu_t G_t^*}{1+\nu_t} + \gamma\rho_t\right)^{-1} \left[\frac{G_t^*}{1+\nu_t} + (1-\gamma)\,\rho_t\right]\gamma\right\}}{(1+\nu_t)\left\{\left(\frac{\nu_t G_t^*}{1+\nu_t} + \gamma\rho_t\right)^{-1} \left[\frac{G_t^*}{1+\nu_t} + (1-\gamma)\,\rho_t\right]\gamma\nu_t + 1 - \gamma\right\}}. \quad (59)$$

The aggregate leverage is maximized when G_t^* is minimized. A potential minimum is obtained the term in the curly brackets in the numerator in the right-hand side of equation (59) is zero, i.e., when

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

This simplifies to

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

It is easy to see from equation (59) 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, ν^{**} indeed characterizes the value of ν_t that minimizes G_t^* and thereby maximizes the aggregate leverage and output. ■

A.3 Calculation of Marginal Rate of Technical Substitution

Differentiating (29) with respect to A_t and N_t gives

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

Evaluating this at a steady state and using equations (55) and (53) in the numerator and the denominator of the term in the square brackets, respectively, give after some algebra

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

Using equation (52) to substitute $\lambda^b/\left(\lambda^e\nu\right)$ for $\Gamma c^{-\frac{1}{1-\gamma}}$ and Proposition 1 to eliminate $\left[\gamma/\left(1-\gamma\right)\nu\right]$ 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.4 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. That contract determines 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 are renting — not 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.

B Modelling an Investment Shock

In Section 4 we introduce an aggregate investment shock by assuming that price and delivery of capital goods are set before the project maturity (forward contracting of capital goods) and that the rate of interest of deposits is also fixed from the outset (fixed deposit contracts). Here we introduce an alternative way to model an investment shock that relaxes these assumptions.

B.1 Timing of events

The timing of events in the investment stage is the following:

1. Contracts are designed and signed
2. The banks decide how much to monitor, the entrepreneurs choose the project (in equilibrium they always choose the good project)
3. The projects are carried out
4. The projects are completed, and the capital goods are sold (to capital rental firms) at price q_t
5. The proceeds are divided between the entrepreneur, the bank and the outside investors (depositors)
6. *Investment shock:* The quality of some of the capital goods is not appropriate. The capital rental firms (that have bought the defective capital goods) are reimbursed by the entrepreneurs and the bankers (but not by the depositors/outside investors) .

B.2 More detailed structure of stages 4–6

4. The projects are completed, and trade in the capital markets takes place. The market price q_t is determined.

- At this point it is commonly known that the fraction $\widehat{p}_H$ ($< p_H$) of the projects have succeeded (the capital goods are of the appropriate quality).
- On the other hand, there is also a (small) fraction $\overline{p}_H$ of projects, whose success is uncertain at this point. We assume that on an average, or as an expectation value, one half of these projects succeed. Then the expected success rate of projects is

$$\widehat{p}_H + \frac{1}{2}\overline{p}_H = p_H$$

- Since trading in capital markets takes place in step 4) the price of capital q_t can only depend on the expected value p_H.
- The capital rental firms pay for the fraction $\widehat{p}_H$ of capital goods (which are known to be of good quality).
- Payments for the remaining projects (fraction $\overline{p}_H$) will take place later on, in stage 6.

5. The proceeds are divided between the entrepreneur(s), the banker(s) and the outside investors (depositors)

- The entrepreneurs get $\widehat{p}_H \times R_t^e$, where R_t^e is the entrepreneur's share of proceeds, as stipulated by the contract
- The banks collect the remaining share $\widehat{p}_H \times R^B$, where $R^B = R - R^e$.
- Notice: The way the bank's share R^B is divided between the bankers ($\widetilde{R}_t^b$) and the depositors/households/outside investors ($\widetilde{R}_t^h$) depends on the realization of the investment shock (thus the tilde)
- The banks pay the depositors $(1 + r_t^d) \times D_t$, where r_t^d is the interest rate on deposits (following Calstrom and Fuerst 1997, we assume for simplicity that $r_t^d = 0$), and D_t is aggregate deposits
- Notice: All deposits D_t (+ plus possible interests $r_t^d D_t$) are paid at this point.
  - What is important here is that the payments to the depositors or outside investors do not depend on the realization of the investment shock (in stage 6)
  - and it is motivated by that the payments to depositors can only depend on commonly observed (macro) variables. The price of capital q_t (determined in stage 4) does not depend on the realization of the investment shock.

– Since the fraction of project that are known to have succeeded ($\widehat{p}_H$) is large, while the fraction of projects that are still pending ($\overline{p}_H$) is small, the banks can always pay the depositors with the income stream $\widehat{p}_H R^B q_t I_t$ they receive in stage 4.

6. It becomes known what share of the remaining (pending) projects has succeeded. The capital goods (of appropriate quality) are delivered to the capital rental firms, as agreed in stage 4, at price q_t per unit of capital. (The capital goods of inappropriate quality are not delivered and there are no payments for these goods.)

- The entrepreneurs get their share R_t^e of the proceeds.
- The banks collect the remaining share $R_t^B = R - R^e$. Since the depositors have already been paid the full amount, in stage 5, the bankers can keep all this money.

B.3 Investment shocks: summary

In sum, the overall success rate of projects in period t, $\widetilde{p}_{Ht}$, can be expressed as follows

$$\widetilde{p}_{Ht} = p_H(1 + \varepsilon_t^I)$$

where ε_t^I is an investment shock.

To keep the analysis simple, we also assume that the ratio

$$\frac{\Delta\widetilde{p}}{\widetilde{p}_H} = \frac{\Delta p}{p_H}$$

is constant. Together with the above, this results

$$\widetilde{p}_L = p_L(1 + \varepsilon_t^I).$$

C Public funding

C.1 Implications for the financing contract

We assume that the government injects an aggregate amount A_t^g of capital to the banking system and an aggregate amount N_t^g of capital to non-financial corporations. Then $a_t^g = \omega_t^b a_t$ is the quantitiy of government-owned capital in an individual bank's balance sheet, and $n_t^g = \omega_t^e n_t$ where $\omega_t^b = \frac{A_t^g}{A_t} \geq 0$ and $\omega_t^e = \frac{N_t^g}{N_t} \geq 0$. Also let $(1 + r_t^{ga})$ and $(1 + r_t^{ge})$ be the (expected) rate of return demanded by the government for its investments in the banking sector, and in the non-fiancial corporations, respectively. Then $R_t^{gb} = (1 + r_t^{ga})\, a_t^g = \frac{1+r_t^{ga}}{1+r_t^a}\omega_t^b R_t^b$ and $R_t^{ge} = (1 + r_t^{ge})\, n_t^g = \frac{1+r_t^{ge}}{1+r_t^a}\omega_t^e R_t^e$ are the (expected) share of the proceeds going to the government in the banking sector and in the non-financial corporate sector. Another way to (re)interprete the conditions of recapitalization is to think that the government buys bank equity at (unit) price $Q_t^b = \frac{1+r_t^a}{1+r_t^{ga}}$ and firm equity at (unit) price $Q_t^e = \frac{1+r_t^e}{1+r_t^{ge}}$ Hence, if the government injects the amount a_t^g of captal into a bank, it obtains the amount $\widehat{a}_t^g = a_t^g / Q_t^b$ of bank equity. Since bank equity has the (expected) rate of return $1 + r_t^a$, the (expected) rate of return to government money is $(1 + r_t^a)\, / Q_t^b b = 1 + r_t^{ga}$. Likewise, if the government injects the amount n_t^g of captal into a non-financial corporation, it obtains the amount $\widehat{n}_t^g = n_t^g / Q_t^e$ of firm equity. Since firm equity has the (expected) rate of return $1 + r_t^e$, the (expected) rate of return to government money is $(1 + r_t^e)\, / Q_t^e = 1 + r_t^{ge}$.

The optimal financing contract solves the following program:

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

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 the investment inputs and outputs

$$a_t + a_t^g + d_t - c_t i_t \geq i_t - n_t - n_t^g, \tag{60}$$

$$R \geq R_t^e + R_t^b + R_t^{gb} + R_t^{ge} + R_t^w. \tag{61}$$

and the equations characterizing the size of government capital injections

$$a_t^g = \omega_t^b a_t \tag{62}$$

$$n_t^g = \omega_t^e n_t \tag{63}$$

and the terms of bank recapitalization

$$R_t^{gb} = (1 + r_t^g)\, a_t^g = \frac{1 + r_t^{ga}}{1 + r_t^a} \omega_t^b R_t^b \tag{64}$$

$$R_t^{ge} = (1 + r_t^{ge})\, n_t = \frac{1 + r_t^{ge}}{1 + r_t^e} \omega_t^e R_t^b \tag{65}$$

Substitution of $R_t^b = \left(1 + r_t^d\right) c_t / \left(q_t \Delta p\right)$, $R_t^e = b\left(c_t\right) / \left(q_t \Delta p\right)$, and equations (64) and (65), into the return-sharing constraint (61) shows that depositors can be promised at most

$$R_t^w = R - \frac{\left(1 + \omega_t^b \frac{1+r_t^g}{1+r_t^a}\right)\left(1 + r_t^d\right) c_t + \left(1 + \omega_t^e \frac{1+r_t^{ge}}{1+r_t^e}\right) b\left(c_t\right)}{q_t \Delta p}. \tag{66}$$

Substituting (66) for the depositor's participation constraint (11) yields

$$p_H \left\{ q_t R - \frac{\left[\left(1 + \omega_t^b \frac{1+r_t^{ga}}{1+r_t^a}\right)\left(1 + r_t^d\right) c_t + \left(1 + \omega_t^e \frac{1+r_t^{ge}}{1+r_t^e}\right) b\left(c_t\right)\right]}{\Delta p} \right\} = \left(1 + r_t^d\right) \frac{d_t}{i_t}. \tag{67}$$

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 (62) and (63) to obtain

$$\frac{d_t}{i_t} = 1 + c_t - \left(1 + \omega_t^b\right) \frac{p_H}{\Delta p} \left(\frac{1 + r_t^d}{1 + r_t^a}\right) c_t - \left(1 + \omega_t^e\right) \frac{n_t}{i_t}. \tag{68}$$

Then combining (67) and (68) shows that the program boils down to

$$\max_{c_t \geq 0} \frac{(1+\omega_t^e)\, b(c_t)}{\widehat{g}\left(r_t^a, r_t^d, r_t^{ga}, r_t^{ge}, q_t, c_t\right)}, \tag{69}$$

where

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

is inverse firm leverage. The unique interior solution to the problem (69) is

$$c_t^* = \frac{\gamma \rho_t}{1+\frac{p_H}{\Delta p}\left(1-\frac{1+r_t^d}{1+r_t^a}\right)+\omega_t^b \frac{p_H}{\Delta p}\left(\frac{r_t^{ga}-r_t^d}{1+r_t^a}\right)}. \tag{70}$$

On the other hand, the banker's incentive and participation constraints (10) and (12) (together with symmetry condition (24)) imply that in equilibrium bankers' monitoring intensity is still also characterized by (25). Then combining (25) and (70) we get a formula for the return to banker-owned capital:

$$1+r_t^{a*} = \left[\frac{\left(1+\gamma\rho_t \frac{I_t}{A_t}\right)\left(1+r_t^d\right) - \omega_t^b\left(r_t^{ga}-r_t^d\right)}{1+\frac{\Delta p}{p_H}}\right] \tag{71}$$

Also, plugging (71) into (25) yields

$$\begin{aligned}
c_t^* &= \left[\frac{\left(1-\omega_t^b \frac{r_t^{ga}-r_t^d}{1+r_t^d}\right)\frac{A_t}{I_t}+\gamma\rho_t}{1+\frac{p_H}{\Delta p}}\right] \\
&= \left(1+\frac{p_H}{\Delta p}\right)^{-1}\left(\frac{A_t-\left(\frac{r_t^{ga}-r_t^d}{1+r_t^d}\right)A_t^g}{I_t}+\gamma\rho_t\right)
\end{aligned} \tag{72}$$

Next, we study aggregate investment and leverage. Equations (60), (62),

(63) and (24) imply that

$$\frac{D_t}{I_t} = 1 + c_t^* - \frac{\left(1 + \omega_t^b\right) A_t + \left(1 + \omega_t^e\right) N_t}{I_t}. \tag{73}$$

Next, applying the aggregation/symmetry condition to (67), and plugging in the expressions (71), (72) and (73), allows us to solve for

$$1 + r_t^e = \left(\left((1-\gamma) \rho_t \frac{I_t}{N_t} + 1 \right) \left(1 + r_t^d\right) - \omega_t^e \left(r_t^{ge} - r_t^d\right) \right) \tag{74}$$

Then, substituting equations (22)), (25), (71), (74) and (73) for equation (67) yields after some algebra

$$\left(\frac{A_t - \left(\frac{r_t^{ga} - r_t^d}{1 + r_t^d}\right) A_t^g}{I_t^*} + \gamma \rho_t \right)^{\gamma} \left(\frac{N_t - \left(\frac{r_t^{ge} - r_t^d}{1 + r_t^d}\right) N_t^g}{I_t^*} + (1-\gamma) \rho_t \right)^{1-\gamma}$$

$$= \left(\frac{p_H}{\Delta p} \frac{\Gamma}{\left(1 + r_t^d\right)} \right)^{1-\gamma} \left(1 + \frac{p_H}{\Delta p}\right)^{\gamma} \tag{75}$$

Equation (75) 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

C.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 entropreneurs, and $p_H (1 + \varepsilon_t) R_t^{ge} I_t$ to the government, while depositors get $\left(1 + r_t^d\right) D_t$. What remains goes to the bank, it this sum is then divided between the bankers ($\widetilde{R}_t^b$) and the government $\left(\widetilde{R}_t^{ga}\right)$:

$$p_H (1+\varepsilon_t) \left(\widetilde{R}_t^b + \widetilde{R}_t^{ga}\right) I_t = p_H (1+\varepsilon_t) (R - R_t^e - R_t^{ge}) I_t - \left(1+r_t^d\right) D_t \quad (76)$$

Next, it is useful to evoke the alternative interpretation of the terms of capital injections. According to this interpretaion, the government has bought bank equity at unit price $Q_t^b = \frac{1+r_t^a}{1+r_t^g}$, and it owns $\widehat{A}_t^g = \frac{A_t^g}{Q_t} = \frac{1+r_t^g}{1+r_t^a} A_t$ bank shares. Since bankers' revenues and the governments' revenues are proportional to their respective ownership shares, one can conclude that the ratio $\widetilde{R}_t^g / \widetilde{R}_t^b$ is the same as given above in equation (64): $\widetilde{R}_t^g / \widetilde{R}_t^b = \widehat{A}_t^g / A_t = \frac{1+r_t^{ga}}{1+r_t^a} \frac{A_t^g}{A_t}$. Plugging this into (76), one can show that the stochastic rate of return to banker-owned capital is

$$1 + \widetilde{r}_t^a = p_H (1+\varepsilon_t) \widetilde{R}_t^b \frac{I_t}{A_t} = (1+r_t^a)(1+\varepsilon_t) + \left(1+r_t^d\right) \frac{D_t}{A_t + \widehat{A}_t^g} \varepsilon_t \quad (77)$$

Here we have used the fact that the expected rate of banker-owned capital $(1+r_t^a)$ (eq (71)) can be also expressed as

$$1 + r_t^a = \frac{p_H (R - R_t^e - R_t^{ge}) I_t - \left(1+r_t^d\right) D_t}{A_t + \widehat{A}_t^g}$$

Next, since $\widehat{A}_t^g = \frac{1+r_t^g}{1+r_t^a} A_t^g$, (77) can be alternatively rewritten as

$$1 + \widetilde{r}_t^a = (1+r_t^a) \left[(1+\varepsilon_t) + \frac{\left(1+r_t^d\right) D_t}{(1+r_t^a) A_t + (1+r_t^g) A_t^g} \varepsilon_t \right]$$

Then the evolution of banker-owned capital is given by

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

To make this equation comparabe to equation (39), we must impose $r_t^{d*} = 0$. This yields equation (43) of the main text.

C.3 The dynamics of government-owned bank capital

Following exactly the same steps as above, one can show that the stochastic rate of return to government-owned bank capital is

$$1+\widetilde{r}_t^{ga}=(1+r_t^{ga})\left[(1+\varepsilon_t)+\frac{\left(1+r_t^d\right)D_t}{\left(1+r_t^a\right)A_t+\left(1+r_t^g\right)A_t^g}\varepsilon_t\right]$$

and the dynamics of government-owned bank capital are given by

$$\begin{aligned}A_{t+1}^g(\varepsilon_t)=A_t^g\lambda^{ga}&\left(\frac{r_{t+1}^K+(1-\delta)\,q_{t+1}}{q_t}\right)(1+r^{ga})\\&\times\left[1+\varepsilon_t+\frac{\left(1+r_t^d\right)D_t}{\left(1+r_t^a\right)A_t+\left(1+r_t^{ga}\right)A_t^g}\varepsilon_t\right]+\varepsilon_{t+1}^{gb},\end{aligned}$$

where $\left(1-\lambda^{gb}\right)$ measures the dividend stream that is repatriated to the government, meaning that the share λ^{gb} of the government's revenues is reinvested in the banks. ε_{t+1}^g is a shock.

Finally notice that the ratio of government-owned and banker-owned bank capital evolves according to

$$\omega_{t+1}^b=\frac{\lambda^{gb}}{\lambda^b}\frac{1+r_t^{ga}}{1+r_t^a}\omega_t^b+\varepsilon_{t+1}^{\omega^b}$$

where $\varepsilon_{t+1}^{\omega^b}$is a bank recapitalization shock. (Note that $\varepsilon_{t+1}^{\omega^b}$ is a simple transformation of ε_{t+1}^{gb}.)

C.4 The dynamics of entrepreneurial capital

It is easy to show that the evolution of entrepreneurial capital follows the same equation (34) as in the basic model, with no capital injections. However, notice that the expected rate of raturn of entrepreneurial capital is now given by (74)), rather than by (35).

C.5 The dynamics of government-owned firm capital

It is easy to show that government-owned firm capital follows the equation

$$N_{t+1}^{g} = N_{t}^{g}\lambda^{ge}\left(1+r_{t}^{ge}\right)\left(1+\varepsilon_{t}\right)+\varepsilon_{t+1}^{ge},$$

where ε_{t+1}^{ge} is a shock. Also notice that the ratio of government-owned and banker-owned firm capital evolves according to

$$\omega_{t+1}^{e} = \frac{\lambda^{gb}}{\lambda^{b}}\frac{1+r_{t}^{ge}}{1+r_{t}^{e}}\omega_{t}^{e}+\varepsilon_{t+1}^{\omega^{e}}$$

where $\varepsilon_{t+1}^{\omega^{e}}$is a firm recapitalization shock. Note that $\varepsilon_{t+1}^{\omega^{e}}$ is a simple transformation of ε_{t+1}^{ge}.

C.6 Proof of Proposition 4

Proof: a) Essentially we need to show that $BCR \geq 1$ for $M \leq \widehat{M}_1$ and $A^g \leq M$. Step 1. Assume that $A^g = M$ and $N^g = 0$. Then BCR is a function of M only, $BCR = BCR(M)$. Using (**??**), one can easily check that $BCR(M) \geq 1$ if and only if $M \leq \widehat{M}_1$, where strict inequality hold for $M < \widehat{M}_1$. Step 2. Assume that $M \leq \widehat{M}_1$ and $A^g < M$. Then $BCR = BCR(M, A^g)$. Using (**??**), one can easily show that $\frac{\partial BCR(M,A^g)}{\partial A^g} < 0$. Since, by Step 1, $BCR(M, A^g) \geq 1$ for $A^g = M$, we clearly have $BCR(M, A^g) > 1$ for all $A^g < M$.

b) Assume that $M \in \left(\widehat{M}_1, \widehat{M}_2\right)$. In the (putative) optimum, both banks and non-financial firms are capitalized, meaning that we must have $BCR = 1$. Using (**??**) one can show that $BCR = 1$ if and only if A^g is given by (48) and N^g is given by (49). Moreover, using (**??**) (second form and third form), one can show that $\frac{\partial BCR}{\partial A^g} < 0$ and $\frac{\partial BCR}{\partial N^g} > 0$, when $M = A^g + N^g$ is kept constant; hence the allocation characterized by (48) and (49) is indeed optimal.

c) a) Essentially we need to show that $BCR \leq 1$ for $M \geq \widehat{M}_2$ and $N^g \leq M$. Step 1. Assume that $A^g = 0$ and $N^g = G$. Then BCR is a function of M only, $BCR = BCR(M)$. Using (**??**), one can easily check that $BCR(M) \leq 1$ if and only if $M \geq \widehat{M}_2$, where strict inequality holds for $M > \widehat{M}_2$. Step 2. Assume that $M \geq \widehat{M}_1$ and $N^g \leq G$. Then $BCR = BCR(M, N^g)$. Using (**??**), one can easily show that $\frac{\partial BCR(M,N^g)}{\partial N^g} > 0$. Since, by Step 1, $BCR(M, N^g) \leq 1$ for $N^g = M$, we clearly have $BCR(M, A^g) < 1$ for all $N^g < M$.

C.7 Further interpretation of Proposition 3

Evidently, the finding that bank capitalization is typically favored to 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- see the term $1+\overline{D}/\left(\overline{QA}\right)$. 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 they are closely linked together. To see the linkage between the benefit calculus and the cost calculus more clearly, let us rewrite the term $\left|\frac{dN}{dA}\right|_{|I^*}$ (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 E.2 one can show that

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

From this equation, one can see that the measure of the relative scarcity of bank capital $\left(\left|\frac{dN}{dA}\right|_{|I^*}\right)$ is related to bank leverage (the term $\left(1 + \frac{\overline{D}}{\overline{A}}\right)$). Next notice that leverage is multiplied by the term $\frac{CORB}{\overline{r}^a}$, where $CORB = \frac{\overline{c}\overline{I}}{\overline{A}+\overline{D}-\overline{c}\overline{I}}$ is a measure of banks' monitoring costs, relative to banks' assets. Also the term $\frac{CORB}{\overline{r}^a}$ has a rather natural interpretation: monitoring costs constitute a part of the costs of financial intermediation, and unlike the return to bank capital ($\overline{r}^a$), this part of the costs 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 thing to notice, however, is that the term $\left(\frac{CORB}{\overline{r}^e}\right)$ is typically quite small; in our baseline calibration

$\left(\frac{CORB}{\overline{r}^a}\right) = 0.11$ while $\left(\frac{\overline{r}^a}{\overline{r}^e}\right)\left(\frac{CORB}{\overline{r}^a}\right) = \left(\frac{CORB}{\overline{r}^e}\right) = 0.33$ (both values are clearly below 1). From this discussion one can see that quite generally we have $BC > CR$ and $BCR > 1$, when M is small enough. .

D Technical appendix

D.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

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

and the law of motion of N_t is

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

Then in steady state we get

$$\frac{A}{N} \equiv \nu = \frac{\lambda^b}{\lambda^e}\frac{R^b}{R^e} = \frac{\lambda^b c}{\lambda^e b} \tag{80}$$

where the last form follows since

$$R^b = c/\left(q\Delta p\right), \quad R^e = b/\left(q\Delta p\right)$$

2. Denote

$$M_t = A_t + N_t$$

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

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

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

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

Workers' Euler equation implies that in steady state

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

Combine

$$R^b = c/\left(q\Delta p\right), \quad R^e = b/\left(q\Delta p\right),$$

with above to obtain

$$G = \frac{1}{\beta}\frac{p_H}{\Delta p}\left(\lambda^b c + \lambda^e b\right). \tag{81}$$

3. Use the equilibrium relations

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

and

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

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

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

and

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

From (80) we get

$$c=\frac{\lambda^e}{\lambda^b}\nu b \tag{86}$$

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

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

Solving ρ from (87) yields

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

Finally plugging (88) into (84) gives

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

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

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

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

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

we get

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

and

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

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):

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

Equation (81):

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

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

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

where

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

Following from the definition of ρ_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 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

$$N = \frac{1}{1+\nu} GI$$

and deposits

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

D.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 to bank capital r^a
- *Excess* rate of return to 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 $(1+r)\left(1+r^b\right)$, where r is the real interest rate earned by workers.

- Non-financial firms' capital ratio

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

- Banks' capital ratio

$$CRB = \frac{A}{A + D - c^* I} = \frac{A}{I - N}$$

  Note that $A + D - c^* I$ is the amount of funds that the banks have allocated to the investment projects; here we have substracted the monitoring costs of the banks $c^* I$ from the amount of total funds $A + D$. [18]

  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

[18] Having the term, cI, facilitates finding the analytical formulation for all parameters.

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

$$CORB = \frac{c^* I}{I - N}$$

The financial parameters to be calibrated are

1. The exit rate of bankers λ^b

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

2. The exit rate of entrepreneurs λ^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 captial to non-entrepreneurial capital in non-financial firms' balance sheets. Then γ

can be re-expressed in yet another way

$$\gamma = \frac{r^a A + c^* I}{r^e N + r^a A + c^* I}$$
$$= \frac{\text{banks' profits + banks' monitoring costs}}{\text{entrepreneurs' profits + banks' profits + banks' monitoring costs}}$$

5. The coefficient of the monitoring function is given by $c^{\gamma} b^{1-\gamma} = \Gamma^{(1-\gamma)}$, then
$$\Gamma = \left(\frac{1+r^e}{1+r^a}\right)\left(\frac{CRF}{CRB}\right)(1-CRF)^{\frac{\gamma}{1-\gamma}} CORB^{\frac{1}{1-\gamma}}.$$

D.3 Ruling out the corner solution

In this appendix we study the conditions under which the no monitoring corner solution, $c_t = 0,\ b(c_t) = b_0$, can be ruled out. Assume that a firm chooses *not* to be monitored: $c_t = 0$. According to equations (19) and (20), the maximum leverage, i_t/n_t, it can obtain is given by

$$\frac{i_t}{n_t} = \frac{1}{g\left(r_t^a, r_t^d, q_t; c_t = 0, b_t = b_0\right)} = \frac{1}{\frac{p_H}{\Delta p} b_0 - \rho_t}.$$

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

$$\widehat{r}_t^e = \frac{\frac{p_H}{\Delta p} b_0}{g\left(r_t^a, r_t^d, q_t; 0, b_0\right)} = \frac{\rho_t}{\frac{p_H}{\Delta p} b_0 - \rho_t}.$$

To rule out the corner solution, we must have

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

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

$$b_0 \geq \frac{\Delta p}{p_H} \frac{1+r^e}{r^e} \rho.$$

One can show that 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

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

where

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

Consequently, the condition can be expressed as

$$b_0 \geq \frac{\Gamma^{1-\gamma}}{1-\gamma} \widehat{\nu}^{-\gamma}. \tag{94}$$

In addition, we seek the condition that guarantees that it is optimal to choose the "good" project and the (interior) level of monitoring c_t^*, rather than the "bad" project with the maximum level of private payoffs b_0 and no monitoring. For this condition to hold in the steady state, we must have

$$\begin{aligned} p_H R - c^* &\geq p_L R + b_0 \Longleftrightarrow \\ b_0 &\leq \frac{\Delta p}{p_H} p_H R - c^*. \end{aligned} \tag{95}$$

To rule out a corner solution, we must find a value of b_0 that satisfies both (94) and (95). Such a value b_0 exists if and only if

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

where we have utilized the steady-state equation $c^* = (\Gamma \widehat{\nu})^{1-\gamma}$. With our calibration, the above condition (96) is satisfied.

D.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 cannot pay depositors (in full) in the no-monitoring case where entrepreneurs choose project with lower success probability p_L (the "bad" project). *Market discipline condition* is given by

$$p_L q_t \left(R - R_t^e\right) I_t < D_t, \tag{97}$$

where the left-hand side gives the banks' revenues in the case of entrepreneurs choosing the "bad" project.

Reformulating the condition (97) in terms of the above observables, involves several steps:

1. Divide both sides of (97) by N_t, and divide and multiply the left-hand side by p_H to obtaine

   $$\frac{p_L}{p_H} p_H q_t \left(R - R_t^e\right) \frac{I_t}{N_t} < \frac{D_t}{N_t} \tag{98}$$

   Then use the following results, definitions and normalizations

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

   to rewrite (98) as

   $$\frac{p_L}{p_H} \left(\frac{q_t}{CRF_t} - 1 + r_t^e \right) < \frac{D_t}{N_t} \tag{99}$$

2. Notice that

   $$\frac{D_t}{N_t} = \frac{D_t}{I_t} \frac{I_t}{N_t} \tag{100}$$

   and use the resource constraint

   $$A_t + N_t + D_t = I_t \left(1 + c_t\right)$$

to obtaine

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

When bankers do not monitor, $c = 0$. Since we assume that bankers may hide to funds reserved for monitoring cI_t, they cannot be used in financing the investment projects. Then re-express

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

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

$$c_t = \frac{c_t I_t}{I_t - N_t}\frac{I_t - N_t}{I_t} = CORB_t\left(1 - CRF_t\right).$$

Given these results, we obtain following

$$\begin{aligned}\frac{D_t}{I_t} &= 1 + c_t - \frac{N_t}{I_t} - \frac{A_t}{I_t} \\ &= 1 - CRF_t - \left(CRB_t - CORB_t\right)\left(1 - CRF_t\right).\end{aligned} \tag{101}$$

Then plugging (101) into (100) and using the fact that $I_t/N_t = 1/CRF_t$ we get

$$\frac{D_t}{N_t} = \frac{1 - CRF_t - \left(CRB_t - CORB_t\right)\left(1 - CRF_t\right)}{CRF_t}, \tag{102}$$

and, finally, plugging (102) into (99), and slightly manipulating, yields

$$\frac{p_L}{p_H}\left(q_t - \left(1 + r_t^e\right)CRF_t\right) < \left(1 - CRF_t\right)\left(1 - CRB_t + CORB_t\right). \tag{103}$$

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

$$q_t = 1 + \rho_t \tag{104}$$

where ρ_t is the NPV of the project. Next, we know that in steady state

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

and

$$\begin{aligned}
&\nu = \frac{A}{N} = \frac{\frac{A}{I-N} \frac{I-N}{I}}{\frac{N}{I}} = \frac{CRB}{CRF} \left(1 - CRF\right), \\
&\frac{\lambda^b}{\lambda^e} = \frac{1 + r^e}{1 + r^a}, \\
&1 - \frac{\lambda^e}{\beta} = 1 - \frac{1}{1 + r^e} = \frac{r^e}{1 + r^e}, \\
&\Gamma = \left(\frac{1 + r^e}{1 + r^a} \right) \left(\frac{CRF}{CRB} \right) \left(1 - CRF\right)^{\frac{\gamma}{1-\gamma}} CORB^{\frac{1}{1-\gamma}}, \\
&\frac{\Delta p}{p_H} = \frac{CORB}{CRB \left(1 + r^a\right)},
\end{aligned}$$

and, finally,

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

We get

$$\begin{aligned}
\rho &= \left(\frac{1 + r^e}{1 + r^a} \right)^{1-\gamma} \left(\frac{CRF}{CRB} \right)^{1-\gamma} \left(1 - CRF\right)^{\gamma} CORB \qquad (105) \\
&\quad \times \frac{CRB \left(1 + r^a\right)}{CORB} \times \left(\frac{CRB}{CRF} \left(1 - CRF\right) \right)^{-\gamma} \times \frac{r^e}{1 + r^e} \\
&\quad \times \frac{r^e \frac{CRF}{1-CRF} + r^a CRB + CORB}{r^e \frac{CRF}{1-CRF}} \times \left(\frac{1 + r^e}{1 + r^a} \right)^{\gamma} \\
&= r^e CRF + \left(r^a CRB + CORB\right) \left(1 - CRF\right)
\end{aligned}$$

4. We plug the results (104) and (105) into (103) to obtaine

$$\begin{aligned}
& \frac{p_L}{p_H}\left(1+r^e CRF+\left(r^a CRB+CORB\right)(1-CRF)-\left(1+r_t^e\right) CRF\right) \\
< & \ (1-CRF)(1-CRB+CORB) \Longleftrightarrow \\
& \frac{p_L}{p_H}\left(1+r^a CRB+CORB\right)<1-CRB+CORB. \qquad (106)
\end{aligned}$$

5. Finally, we first re-express

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

Noting that

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

equation (106) can be rewritten as

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

The market discipline condition (97) is rewritten as follows

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

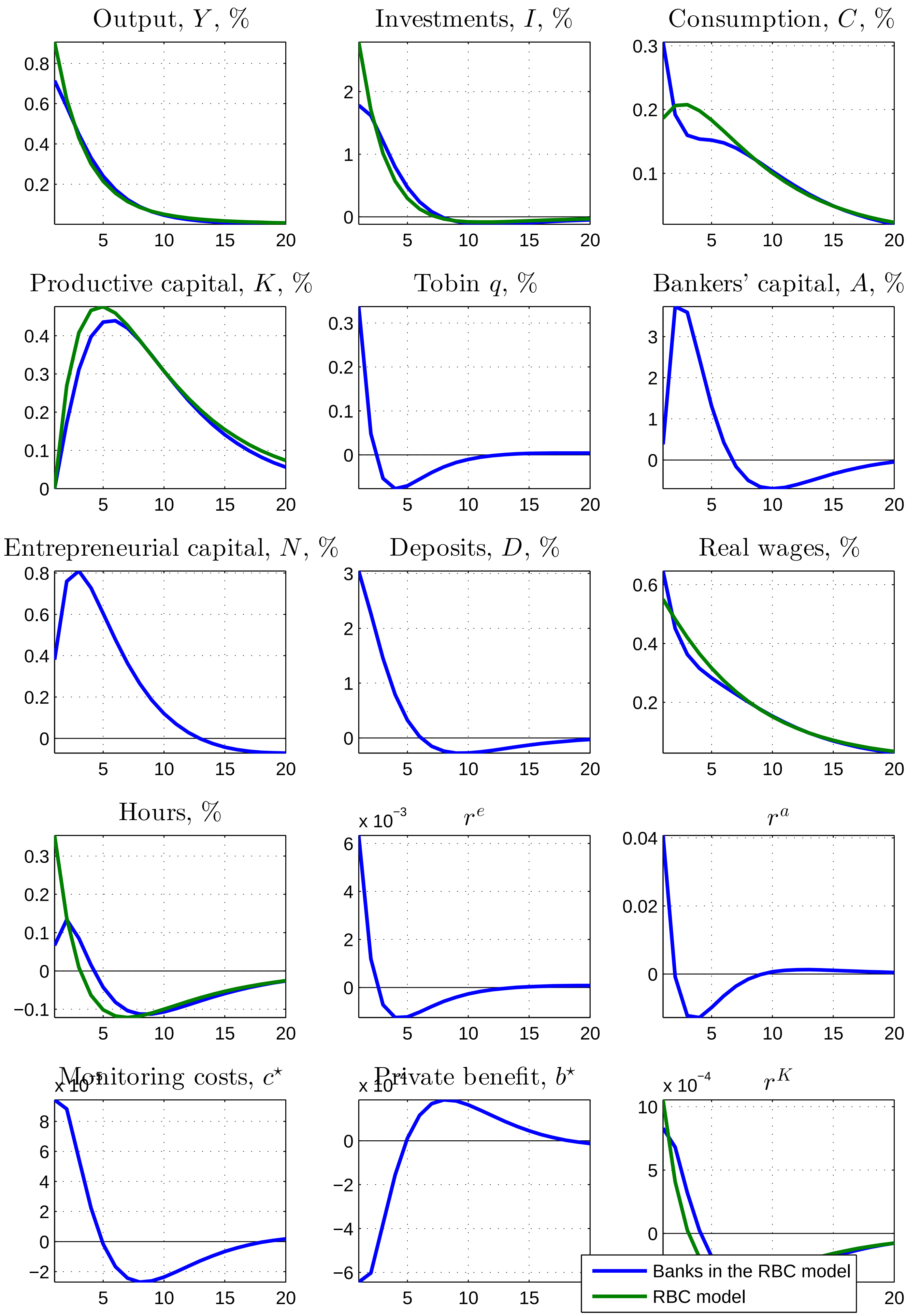

Figure 1: Impulse responses to a technology shock

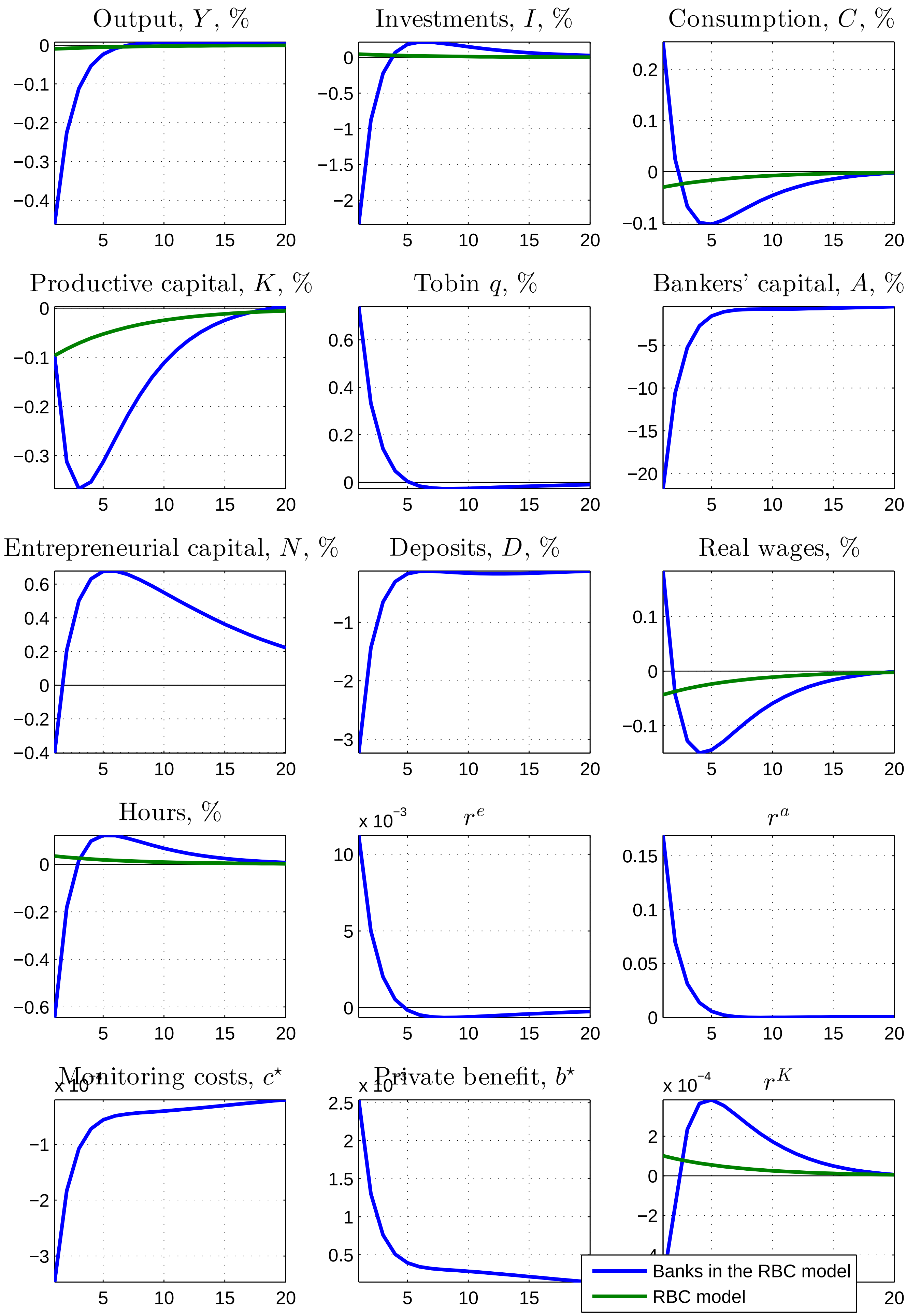

Figure 2: Impulse responses to a negative investment shock

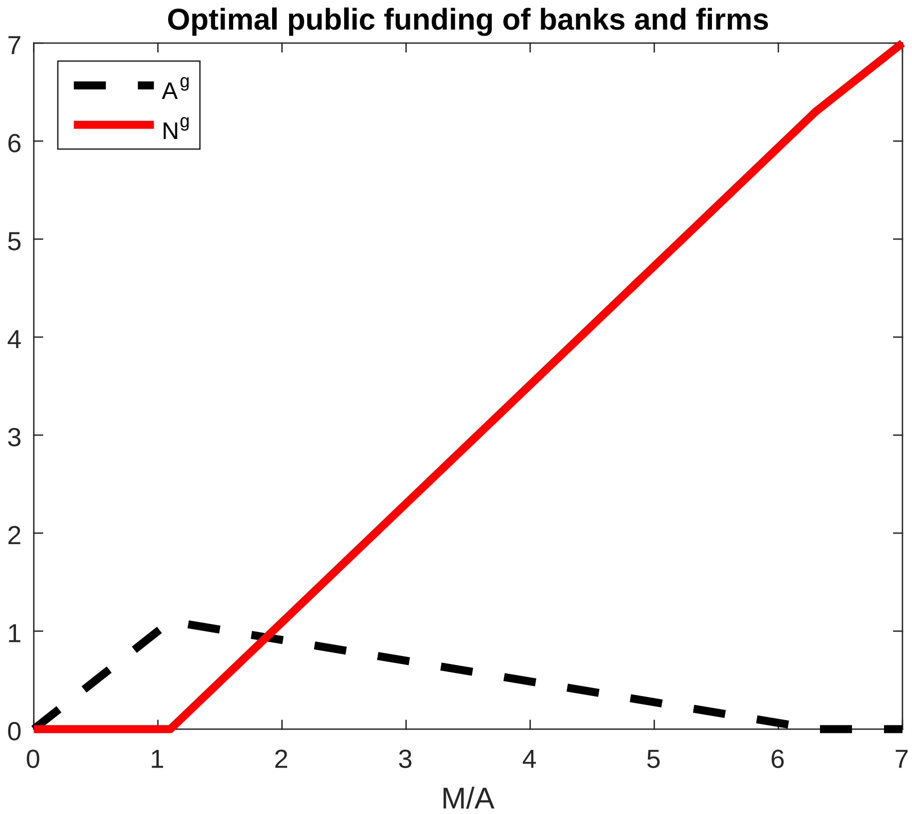

Figure 3: Pecking order of public funding